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# THE COMBINE HARVESTER IN WESTERN CANADA [1]

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The idea of combining harvesting operations into one machine started back in 1836 when Briggs & Carpenter patented the combined harvester and thresher, using the ground drive. Following 1836, a series of American patents were registered embodying many of the elements of success. In 1845, Ridley of Australia built a machine which attracted considerable attention for cutting and threshing grain in one operation. The developments of his machine are best illustrated in the present Sunshine combine, built in Australia. Ridley developed the comb and stripper, while in the American machines were developed the cutter bar knife and reel.

The variations in speed due to the ground drive caused a considerable amount of experimental work during 1907 to 1912, when the first internal-combustion engine driven combines made their appearance in Washington.

The self-propelled combine was developed in 1915 but did not materialize to any extent until after the war. It has been developed in Australia more than in this country.

The territory in which the combine is used has widened every year since 1867, when the first combine was put to work in California. During the war the use of the combine spread rapidly east through Western Kansas, the Panhandle of Texas, Western Oklahoma, Eastern Colorado and Western Nebraska, resulting from the scarcity and high cost of labour.

## COMBINES IN WESTERN CANADA

In 1910 Shand & Edmonds imported a standard level land twenty-foot Holt combine from Stockton, California, to a tract of light uniform land west of Welby Siding, Saskatchewan. The power was supplied through both ground wheels, the grain was delivered in bulk to a grain wagon, hitched to the rear of the machine. About 600 acres of Red Fyfe wheat, commonly raised at that time, were successfully harvested during the falls of 1910, 1911 and 1912. The wheat shipped generally graded tough. In 1913, 600 acres of flax were partly harvested when winter set in, and the balance was harvested during the next spring. Shand & Edmonds discontinued farming in 1914 and the machine was not used further because their successors could not use the big power machinery.

In 1922 the Massey Harris Company co-operating with the Dominion Government placed an experimental machine on the Dominion Experimental Farm at Swift Current, Saskatchewan. The International Harvester Company also placed an experimental machine at Cabri, Saskat-

1 This paper was read before the Western Canadian Society of Agronomy, December, 1930.
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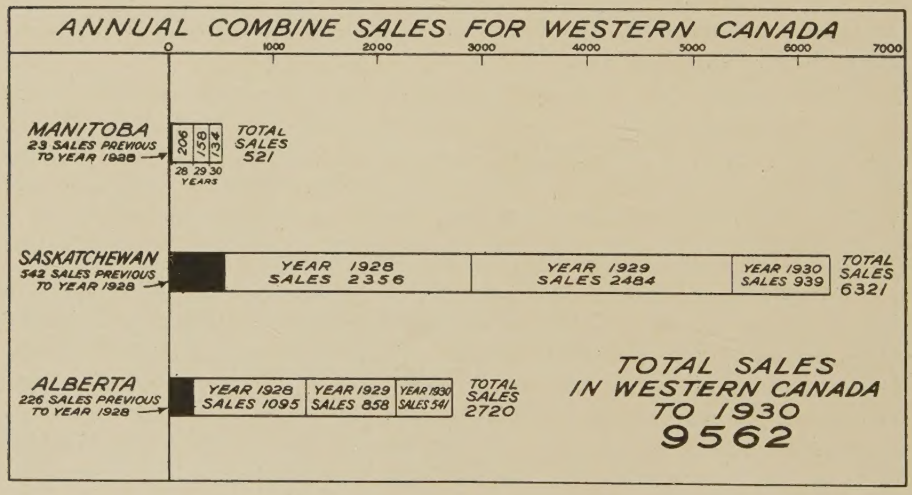
chewan, in order to study the application of the machine to Saskatchewan conditions.

In 1923 a number of Saskatchewan farmers from the Rosetown district tried to buy combines from the farm machinery companies, but were not successful. In February of 1924, Mr. F. B. Lynch of Forgan, Saskatchewan, bought a sixteen-foot Case combine in Kansas City, Mo., and had it delivered to his farm in June. The same year Mr. M. M. Hess and the McKinnon Brothers of Hughton, Saskatchewan, bought combines and harvested a portion of the 1924 crop. The use of the combine in the three prairie provinces has increased almost beyond practical bounds since 1924.

*Annual combine sales for Western Canada.*

| Year | Manitoba | Saskatchewan | Alberta | Total | Total Combines in Use |
|---|---|---|---|---|---|
| 1925 | | 12 | 5 | 17 | 17 |
| 1926 | 2 | 148 | 26 | 176 | 193 |
| 1927 | 21 | 382 | 195 | 598 | 791 |
| 1928 | 206 | 2356 | 1095 | 3657 | 4448 |
| 1929 | 158 | 2484 | 858 | 3500 | 7948 |
| 1930 | 134 | 939 | 541 | 1614 | 9562 |
| Total | 521 | 6321 | 2720 | 9562 | |




The scarcity, high cost, and irresponsible type of farm labour available during the harvest, along with short crops, tended to pave the way for the wide-spread use of the combine. Also, the difficulty experienced in obtaining the services of the custom threshing rig, raised the question of the purchase of either a small thresher or a combine. In many instances the purchase of the combine was made without much consideration of the topography of the land or the nature of the maturity of the crop.

Naturally, the use of the combine was confined during the first few years to the south western and west central portions of Saskatchewan and

the south eastern portions of Alberta, because of the lay of the land and the aridity of the climate. However, a few of the more imaginative farmers in the more humid sections of Western Canada purchased combines even though conditions were not ideal for their use. As a result, the use of the combine has spread all over Western Canada.

## "Straight Combining"

The ideal use of the combine is to harvest the crop in one operation, when the grain is dry enough to store or ship without dockage due to moisture content. A considerable difficulty has been experienced in not being able to wait until the crop is entirely ripe.

1. The first discovery was that grain which was ordinarily considered uniformly ripe for binder harvesting was not ready for the combine.

2. The green heads ripened and dried very slowly in September and October, seriously delaying the harvest operations.

3. The presence of green weeds in the crop was detrimental to the satisfactory use of the combine in that the greater portion of the green weed was not separated from the grain and the grain absorbed the moisture from the weeds, impairing the quality of the grain.

4. The grain in all low spots and lower areas was not dry enough to thresh until long after the remainder of the field.

5. The over-ripe grain shattered quite badly, due to the action of the wind while standing.

6. Grain which went down due to the action of the saw-fly could not be picked up by the combine similar to lodged grain, since when grain goes down because of the saw-fly infestation, the heads go down first and cannot be picked up by the reel and table or the comb of the combine.

7. The standing grain absorbed sufficient moisture from the air during the night to make the grain unfit to thresh until late in the morning, thus reducing the amount of available daylight for harvesting.

8. Ridged or non-uniform tillage along with loose stones or roots increased the hazard of harvesting short crops.

There has been the normal development resulting from the use of combination machines in that the farmer has seriously studied the application of the method of harvesting to conditions in Western Canada and is definitely farming for the combine, while the farm machinery manufacturer is attempting to design machinery to harvest the crops as grown in Western Canada.

## Farming for the Combine

In farming for the combine, pure seed which would ripen early and not shatter excessively was used, replacing the mixed varieties formerly used. The seed was more carefully prepared, stones and roots were lifted, the seed bed was prepared so that the surface was uniform and free from weeds. The practice of light fall tillage with the proper tillage in the spring to destroy the small weeds and prepare the soil was followed. The seeding was done early and as nearly all at one time as possible. The general aim of the farmer was to produce a crop which would ripen early and uniformly, and which would be reasonably free from or ahead of the weed growth.

Farming for the combine has been successful in almost every district in Saskatchewan. Large areas were "straight combined" before the rains in September of 1930. In many districts the only harvests completed before these rains were where the farmers had specifically farmed for the combine.

### Adapting the Combine to the Crop

The development of the combine to meet the conditions found in Western Canada has been quite marked. The first combines in Western Canada consisted of two general types. The one was a light machine equipped with a cutting and threshing mechanism and a single shoe and chaffer with a rotary recleaner for the grain. The other was practically the same, but for the recleaner, which was of the shoe type mounted above the straw rack within the machine. Both machines were fitted above the straw rack within the machine. Both machines were fitted with waggon hitches for disposition of the grain.

It was found that the heavier crops with tough long straw and high travelling speeds required stronger combines, and more powerful engines for driving the combine, with special equipment for recleaning the grain and grain tanks of some description mounted on the combine. The grain tanks were designed to meet the requirements as to load according to the size of the average truck used for hauling grain to the elevator.

The use of the power take-off as a means of driving the combine from the tractor was discarded in a year because of variations in speed for different loads and grades.

The corrugated bar cylinder and the peg toothed cylinder have both been used quite satisfactorily. There are advantages and disadvantages of each, but when adjusted correctly and maintained properly, the quality of threshing is of very high order. The width of cut varies with the size of fields and topography of the land upon which the combine is used. The following indicates the sizes selected in 1930.

*Combine Sales, by sizes, in 1930.*

| Size in Feet | Manitoba | Saskatchewan | Alberta | Total by Sizes |
|---|---|---|---|---|
| 10′ | 28 | 51 | 23 | 102 |
| 12′ | 62 | 433 | 165 | 660 |
| 14′ and 15′ | 11 | 153 | 77 | 241 |
| 16′ and 16½′ | 33 | 268 | 244 | 545 |
| 20′ | | 34 | 32 | 66 |

The use of the screw in place of the drapers on the table has been used with a considerable degree of success. The use of the Australian machine with the comb, sickle and spirals is being watched with interest as it is used in the various districts in Western Canada.

Although the general type of combine seems to be reasonably standard, there is a considerable amount of experimental work being carried on by each machinery company so that the crop conditions of Western Canada may be more perfectly met.

## The Windrow Harvester

In 1925 combines were quite generally used by the Campbell Farming Corporation in Eastern Montana. The hazards of straight combining were too great for the areas which were to be harvested. Consequently, the idea of windrowing was developed. They used four binders forming a windrow from a 32 foot swath. They used a hay loader trailed back of the combine table as a pick-up and successfully windrowed and picked up a portion of the harvest.

The Western Harvester at Stockton, California, and the International Harvester Company developed windrow harvesters and pick-up machines, which were used in Western Canada in the fall of 1927. The Western Harvester developed the end delivery windrow harvester, while the International developed the centre delivery machine. There was a great deal of rain during the fall of 1927 and much of the stooked grain started to grow. The stooks as well as the windrows were wet through during a two weeks rain in September and yet the grain in the windrow dried and was picked up and threshed. The grain in the windrow bleached badly but was of good quality otherwise.

Winter set in on November 3rd, so that vast areas of standing grain, grain in the windrow and in the stook was not threshed until the spring of 1928; the spring was dry and windy, so that the grain threshed in the spring graded higher than it had been the previous fall. The windrowed grain threshed in the spring was badly bleached but was hard and dry.

Since 1927, all of the machinery companies built windrow machines. Some developed the end delivery and others the centre. Most of the windrowers were operated by a ground drive, while some used the power take-off. An enormous amount of experimental work was done co-operatively by the farmers and the machinery companies on the windrowers and pick-ups. The following indicates the use of the windrowers and pick-ups.

*Yearly sales of Windrowers and Pick-up Attachments.*

| Year | Windrowers | Pick-up Attachments |
|---|---|---|
| 1927 | 41 | 41 |
| 1928 | 1434 | 1418 |
| 1929 | 1138 | 1175 |
| 1930 | 494 | 624 |
| Total | 3107 | 3258 |

The use of the windrow harvester increased the cost of harvesting, but offered advantages in handling weedy or irregularly ripened crops with the combine. A considerable amount of trouble was experienced in the use of both the windrow machines and the pick-ups. The machines were not designed for the high speed and heavy crops to which they were subjected and consequently had to be re-designed. The delivery of the cut grain on to the stubble was particularly studied in order to form a windrow

which would be supported by the stubble. It was found necessary to deposit the grain on to a metal shoe or slide in order to prevent it from going to the bottom of the stubble. Also, the length of the stubble left to support the windrow was important. Too long stubble was found to be as bad as too short. The operation of the windrow at too high speeds tended to pound down the stubble until the windrow could not be supported up off the ground. A considerable amount of growing, which occurred in windrowed grain this fall, was caused because of operating the machine at too high a speed and driving the windrow down through the stubble to the ground. Quite a satisfactory windrow can be made by operating either the centre delivery or end delivery windrower carefully.

### Pick-up Attachment

The development in the pick-up attachments for combines has been along two lines, one to elevate the grain and deposit it down upon the table canvas, while the other is to raise the windrow out of the stubble only enough to place it on the table. Considerable difficulty has been experienced in the operation of the pick-ups for heavy crops. They were continually falling to pieces and over-loaded, the trouble being due to the fact that it was impossible to draw the combine slowly enough with the average tractor. The designs have been quite successful in eliminating the hazard of picking up loose stones, but the loose root still is picked up and gives trouble in the cylinder.

Either type of pick-up will gather the windrow even from the ground without much loss. Some farmers have gone so far as to eliminate the man on the combine when using the pick-up and operate the entire outfit from the tractor. The combine pick-up floats on the shoes of the pick-up, so that it is not necessary to have an operator to keep the table at the correct height. The operator on the tractor watches the windrow as it is picked up and fed into the cylinder. Where it is necessary, one man can harvest a considerable amount of grain per day.

### The Header Barge

The combine has been used as a semi-stationary thresher in combination with the use of the header barge. A number of farmers in Saskatchewan and Alberta have not been satisfied with the use of the combine as a harvesting machine for their crop. They have not wanted to wait after binder harvest was possible and have built barges to cut the grain into as a form for small stacks.

Mr. Hallam of Acadia Valley, Alberta, built the first header barges forming small stacks which were conveyed to the threshing machine by the use of heavy buck rakes. Mr. Jerome Ternier of Ponteix built the first one in Saskatchewan and used it in connection with a twelve foot header. His experience was very favourable to that method. He found that the grain and weeds would dry and cure quite satisfactorily in the small stacks and would thresh out a very good quality.

The Dominion Experimental Farm built a barge and operated it in connection with a twelve foot header. The following extract from the 1928 Report of the Dominion Experimental Station at Swift Current

indicates the results of the experiments:— "The header-barge showed up very well in the past season. Fields where ripening was particularly uneven and fields infested by green weeds were successfully harvested by the header-barge. The stacks dried out perfectly and the grain when threshed was of good colour and the grades obtained compare favourably with those obtained for binder-cut grain, straight-combined grain and swathed grain. There still remains the possibility of heavy rains of considerable duration wetting the stacks to the bottom. This happened at Arrowwood, Alberta, in 1927, where the October rainfall was very heavy. Those stacks had to be scattered on the ground. Apart from this possibility there seems to be nothing to prevent the use of the header-barge as an auxiliary to the combine, either in conjunction with the swather or in its place".

The Wehrhahn Brothers at Rockhaven, Saskatchewan, have built a barge on somewhat the same plan, and have used it in connection with their twenty foot windrower. They have the stack built upon a conveyer floor in the barge, which discharges the stack after the barge has been tipped. They have used the barge for two years. This year the stacks were snowed under twice and were in heavy rains during September and October. The grain was of a number two grade when cut, as estimated by Mr. Wehrhahn. It was threshed during December and was graded No. 2 Hard. In all of the barges discussed, the grain has been delivered into the centre of the barge and has been tramped by a man in order to make the stack fill the barge and be hard in the centre. The stacks turned the rain and snow as well as the wind quite satisfactorily and made it possible for the grain to be cut and stacked before the bad weather and threshed in good condition after the weather had settled.

### The New Way Harvester

The New Way Harvester is built along somewhat similar lines to the header barge. It consists of a header and elevator and a cylindrical barge. The barge is built with a revolving floor with packers placed around the side. The stack is revolved as it is formed. The grain is delivered into the centre of the barge from the header so that the stack will be firm in the centre and have a tendency to shed the rain. The stacks are discharged off the rear of the machine in such a way that they are left upright and firm so that they will resist wind and weather.

We have had very few reports with regard to this machine. The earlier experimental work in Manitoba with similar machines was not encouraging. A report from Headingly, Manitoba, indicated that for rye and flax harvested this year the stacks weathered two weeks of heavy rain and dried out nicely. The flax graded No. I no dockage. Reports from north of Tisdale, Saskatchewan, indicate that after weeks of rain and snow some of the stacks were sufficiently dry to thresh while others were still frozen through. This would indicate that considerable study of the formation of the stack should be made when used in heavy crops, and where heavy precipitation is apt to occur. Wet weather during harvest is the "bugbear" of the north and must be considered when attempting to build a machine for harvesting grain.

There are two methods of threshing the grain from the stacks. One is to draw the combine from stack to stack, threshing the stacks in place. The other is to use a heavily constructed buck to lift the stacks and convey them to a threshing machine where the grain is threshed.

Methods of harvesting satisfactorily for one type of farming may not be satisfactory for the other. Machinery satisfactory in the dry, short crop districts may not be satisfactory in the more humid, heavy crop areas. The use of the combine has reduced the labour requirements per farm and lightened the harvest load for the household. Where its use is at all practical the cost of harvesting has been reduced. Consequently, the use of the combine has fitted in more or less perfectly from both the mechanical and economic standpoint in Western Canada.

### The Evolution of the Harvester

*Illustrations supplied through the courtesy of the International Harvester Company in connection with the celebration of the one hundredth anniversary of the invention of the reaper by Cyrus H. McCormick. Figue 2 shows the first reaper invented by Mr. McCormick. It is said that this reaper included all the essential principles of the modern machine later developed by the McCormick-Deering division of The International Harvester Company.*

*The Canadian Society of Technical Agriculturists extends its congratulations on this occasion and expresses its appreciation of the great service of The International Harvester Company of Canada to Canadian agriculture.*

Figure 1.

Figure 2.

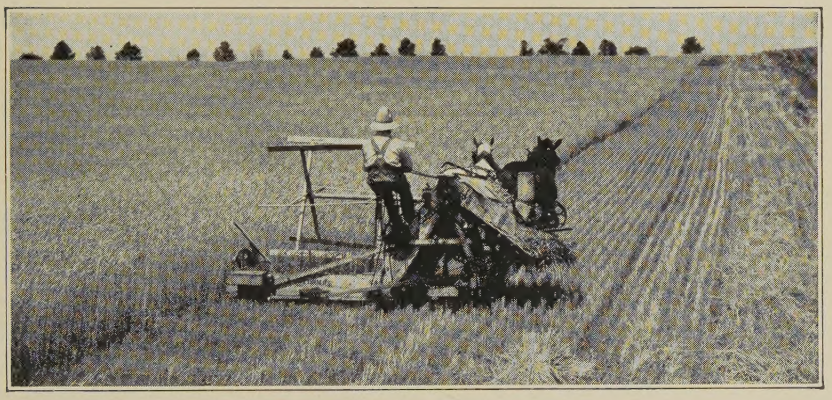


Figure 3.

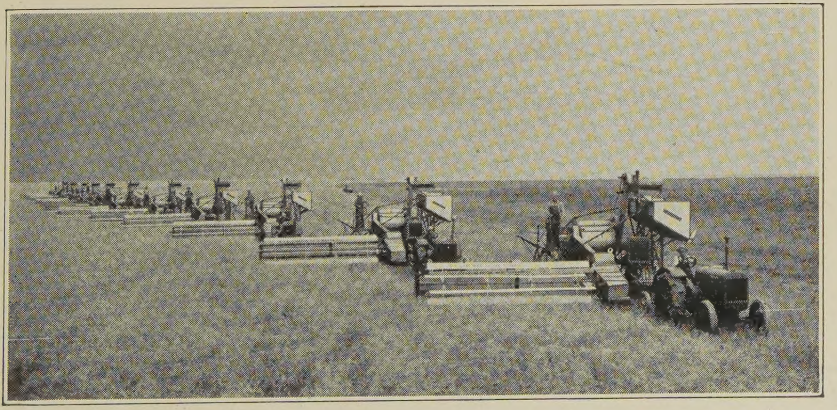


Figure 4.

# FACTOR RELATIONS IN WHEAT FOR RESISTANCE TO GROUPS OF PHYSIOLOGIC FORMS OF *PUCCINIA GRAMINIS TRITICI* [1]

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## Introduction

Studies of the inheritance of rust resistance in wheat have been given a great deal of attention in recent years. The inheritance of reaction to stem rust under field conditions has been studied by several investigators (*3, 9, 10, 11, 13*), and much valuable information has been obtained. The inheritance of the reaction of wheat in the seedling stage to specific physiologic forms of *Puccinia graminis tritici*, of which over one hundred have now been identified, has also been determined in several different crosses (*1, 3, 5, 9, 10, 11*). Two facts of great importance to the wheat breeder have been established by these studies. It has become quite clear that the reaction of wheat varieties and hybrids in the seedling stage, as determined by greenhouse studies, is not necessarily a criterion of the reaction under field conditions. This fact was first demonstrated by Hayes and his associates (*10, 11*), who found that certain wheat varieties and hybrids showed a high degree of rust resistance under field conditions, in spite of susceptibilty in the seedling stage under greenhouse conditions to several physiologic forms. Later, Goulden *et al* (*3*) reported the results of an investigation which showed that the high field resistance of the variety H-44-24 was inherited quite independently of the seedling reaction in the greenhouse to several physiologic forms.

That the existence of a large number of physiologic forms was a less serious matter from a breeding point of view than it at first appeared to be, also became evident from the results of certain greenhouse studies. In 1923 Aamodt (*1*) showed that the inheritance of immunity of the variety Kanred to eight physiologic forms was governed by a single pair of factors. Thus any line of a cross involving the Kanred immunity which is immune to one form will, in all probability, also be immune to the other seven forms which belong to this "group". In a cross between Marquis and H-44-24, Goulden *et al* (*3*) found that the factors which governed the reaction to form 21 were also responsible for the reaction to five other forms namely, 9, 14, 15, 17, and 34. From the results of a study of a Vernal Emmer × Marquis cross, Harrington and Smith (*6*) concluded that the inheritance of the reaction to four physiologic forms was governed by one pair of factors.

The investigation described here was undertaken with a threefold purpose. First, to study the reaction of wheat hybrids to as large a number of physiologic forms as possible, with a view to finding out how many might be contained in a single group. Second, to determine to what extent a group identified in one cross might be found intact in a different cross. The

1 Contribution from the Cereal Division, Experimental Farms Branch, Department of Agriculture, Ottawa, Canada. Presented to the faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

2 Cereal Specialist.

third aim was to study the importance of such groups identified in the greenhouse in relation to the field reaction.

## Experimental Procedure

The investigation included a study of three different crosses, namely: Marquis × H-44-24, Marquillo × H-44-24, and Garnet × Double Cross. The parental varieties Marquis and Garnet were produced at the Central Experimental Farm, Ottawa. H-44-24 was selected by E. S. McFadden (*12*) from a cross between Yaraslov emmer and Marquis. Marquillo and Double Cross were produced at University Farm, Minnesota. The former variety arose from the cross Marquis × Iumillo, and the latter from the cross (Marquis × Kanred) × (Marquis × Iumillo). Details of the origin of Marquillo and Double Cross have been published by Hayes *et al* (*11*).

The hybrid material was obtained in the manner about to be described. One plant was taken at random from each of 1000 $F_3$ lines of each cross. The seed from each of these plants was divided into three lots, one of which was used to study the reaction to physiologic form 36, another to study the reaction to form 21, and the third lot was increased in the field in the following year. The lines to be used for further study were selected on the basis of their seedling reaction in the greenhouse to forms 36 and 21. The purpose of this selection was that of eliminating, as far as possible, the segregating lines. Forms 21 and 36 were chosen as a basis for selection because Goulden *et al* (*3*) had concluded that the reactions to these two forms were inherited independently. Thus the selected lines could be proportioned according to their reaction to at least two groups of physiologic forms, and the likelihood of selecting lines which would segregate for their reaction to any one form was greatly reduced. We shall see later that the inheritance of reaction to forms 21 and 36 is not independent, even in the cross Marquis × H-44-24 which Goulden *et al* studied. Concerning the other two crosses nothing was known regarding the relation between the reactions to these two forms. However, they proved quite satisfactory for the purpose of the selection of lines for the more extensive study. The number of lines selected was 116 from Marquis × H-44-24, 228 from Marquillo × H-44-24, and 114 from Garnet × Double Cross. The increase plots provided an ample supply of seed for further study of the selected lines.

The greenhouse studies were carried on during the period extending from September 1929 to June 1930, except, of course, those concerned in the reactions to forms 21 and 36, which had been conducted the previous winter. The physiologic forms used in the study of each cross are listed in table 1. The numbers by which the various forms are known are those assigned at the office of the Department of Plant Pathology of the Minnesota Agricultural Experiment Station. Cultures of all forms used were made available through the courtesy of Dr. Margaret Newton, Dr. T. Johnson, and Mr. A. M. Brown of the Dominion Rust Research Laboratory.

The seed was planted in five-inch pots, and all inoculations were made by hand. After inoculation the seedlings were incubated for 48 hours. On account of time and space limitations, replication of the tests would have restricted the study to a much smaller number of physiologic forms. For this reason only one pot containing from ten to fifteen seedlings was used

TABLE 1.—*Physiologic forms with which the hybrid lines of the three crosses were inoculated.*

| Cross | Physiologic Forms |
|---|---|
| Marquis × H-44-24 | 14, 15, 21, 27, 29, 30, 33, 35, 36, 48, 49, 50, 52, 53, 57. |
| Marquillo × H-44-24 | 14, 21, 27, 29, 30, 33, 35, 36, 48, 49, 50, 52, 53, 57. |
| Garnet × Double Cross | 14, 21, 29, 30, 33, 35, 36, 48, 49, 50, 53. |

for each determination. Each batch of hybrid material tested, consisting of not more than eighty lines, was accompanied by the parental varieties concerned, and also three or four varieties specially selected to check the purity of the rust cultures. An attempt was made to keep a photographic record of all types of reaction in each cross to each form, as well as of the parental varieties. In some cases, however, photographs were not obtained. Since no other record of the parental varieties was taken, the data for the parental reactions given in table 2 were obtained partly from the photographs, and partly from the table of varietal reactions published by Newton *et al* (*14*).

TABLE 2.—*Reactions of parental varieties to the physiologic forms used.*

| Physiologic Form | Marquis | Garnet | Marquillo | Double Cross | H-44-24 |
|---|---|---|---|---|---|
| 14 | R | S | R | O | SR– |
| 15 | S | | | | SR |
| 21 | S | S | R | O | SR |
| 27 | SR | | variable | | R |
| 29 | S | S | SR | O | SR |
| 30 | S | S | MS | O | R |
| 33 | SR– | S | R | R | R |
| 35 | S | S | MS | SR– | R |
| 36 | S | S | MS | S | R |
| 48 | R | S | R | O | SR |
| 49 | S | S | SR | O | R |
| 50 | SR | S | MS | O | R |
| 52 | S | | MS | | R |
| 53 | R | S | SR | O | SR– |
| 57 | S | | MS | | R |

The different reactions were described in the following manner: O= immune, R = highly resistant, SR– = moderately resistant, SR = semi-resistant, MS = moderately susceptible, and S = susceptible. As a general rule an accurate classification could be effected. Occasionally, however, some difficulty was encountered. In spite of the fact that the greenhouse was artificially illuminated, reactions in the middle of the winter were not entirely satisfactory. Lines giving reactions intermediate between certain of the main types were often found, due probably to modifying factors. Such lines usually gave reactions approximating one class more than another, and were placed in the class which

they most nearly approached. Some errors were inevitable, but the results indicate that they were comparatively few in number.

Quite a number of lines segregated, some of which were undoubtedly heterozygous. In view of the fact that only from ten to fifteen seedlings were used for each determination, it was to be expected that some lines classified as homozygous for their reaction to forms 21 and 36 should have been in reality heterozygous. Some lines also contained varying numbers of seedlings giving aberrant reactions as a result of natural crossing in the field. The facts presented by Hayes (*8*), and by Goulden and Neatby (*4*) show that natural crossing in wheat is a common occurrence; its effect on studies such as this is discussed by Neatby and Goulden (*13*). When more than one seedling differed in reaction from others of the same line to a particular form, the line was recorded as segregating for reaction to that form. Data concerning the segregating lines are not included in the tables for two reasons. In the first place the class is incomplete due to the occasional failure of a heterozygous line to show more than one type of reaction. The second and chief reason is that the addition of columns in the tables for the accommodation of the segregating classes renders the relationships less directly obvious. On account of the exclusion of segregating lines, and because infection sometimes failed, the number of lines will be found to vary from one comparison to another.

Before proceeding to an examination of the data, it should be pointed out that the chief emphasis is placed on the relationship, if any, between the reactions of the hybrids to different physiologic forms. The actual type of reactions which occurred, and their relation to the parental reactions will not be discussed except in cases of particular interest. Since the parental reactions are recorded in table 2, the reader can make any desired comparisons. It may be noted at this point that in some cases only the parental types of reaction were recovered in the hybrids; in other cases true breeding intermediate or more extreme types were found; and in the cross Garnet × Double Cross the susceptibility of Garnet was, in certain cases, not recovered.

## Experimental Results

### Greenhouse reactions

*Marquis × H-44-24*

The physiologic forms used in the study of this cross are listed in table 1. The results can be most readily comprehended by relating the reactions to forms 21 and 36 to the reactions to other forms. In order to illustrate the basis of classification, infection types in the case of form 36 are shown in figure 1.

We shall first consider the relation between the reactions to form 36 and forms 35, 49, 52, and 57. The figures are given in the right hand section of table 3. Consider, for example, the relation between the reactions to forms 36 and 52. All lines resistant to 36 are likewise resistant to 52, and all lines susceptible to 36 are susceptible to 52. It will be observed that the SR and SR– classes do not agree so well. This is due partly, at least, to a greater difficulty in the accurate classification in these classes. It is also

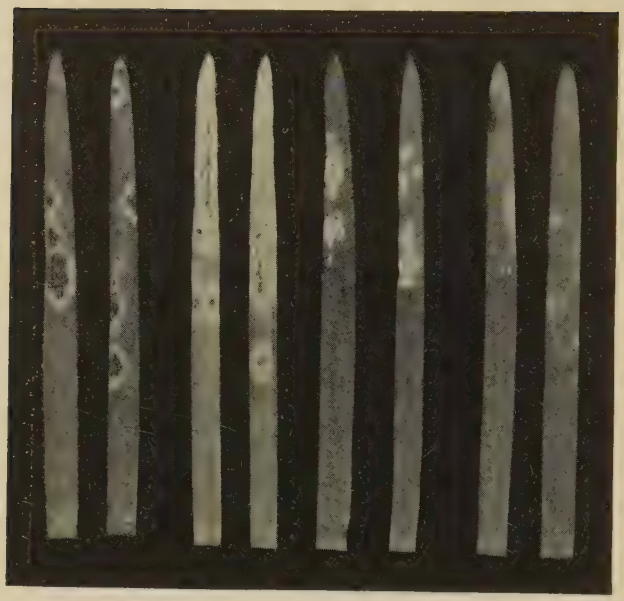

Figure 1. Reactions of hybrids to form 36 in the cross Marquis × H-44-24. Left to right: S, SR, SR- R.

possible that minor factors may modify the reaction to one form, and be without effect on another, even though the main differences in reaction to both forms may be governed by the same genetic factors.

It should be pointed out here that these and the data given below are most readily explained on the assumption that the reactions to forms belonging to the same group are governed by the same genetic factors. It is possible, however, that we are dealing with distinct factors rather closely linked, since the relationships which are demonstrated are not by any means absolute. However, a definite correlation was observed between ease of classification and close relationship. It will be observed that the four comparisons shown in the right hand section of table 3 give a very good agreement between the reaction to form 36 and the reactions to forms 35, 49, 52, and 57, at least as far as the R and S (R and SR in the case of form 35) classes are concerned. It is significant that the differences in type of reaction to individual forms were fairly clear cut, and errors in classification were probably much less frequent than was the case with certain other forms which show less clear, though significant, relationships. The possibility of the action of closely linked factors cannot be dismissed or confirmed without checking the reaction of lines supposedly misplaced. The likelihood of different factors operating in the reactions to the five forms under discussion, all closely linked, appears rather remote. The explanation on the basis of the same factors governing the reaction to all forms of this group is, therefore, probably correct.

There is no susceptible class in the case of form 35, but as there is a clear positive relationship between the reactions to forms 35 and 36, the possibility suggests itself of the difference between semi-resistance and sus-

ceptibility to form 36 being governed by a factor which has no effect on the reaction to form 35. This point is dealt with at the end of the discussion of this cross, where the question of the number of factors in operation is considered. It may be stated here, however, that the available data indicate that the reactions to these two forms are governed by the same factors. It is possible that the absence of a susceptible class in the case of form 35 may indicate that this form is somewhat less virulent on H-44-24 × Marquis hybrids than form 36.

TABLE 3.—*Number of lines in each infection class of forms 21 and 36, and forms 35, 49, 52, and 57 in the cross Marquis × H-44-24.*

| | | Form 21 | | Form 36 | | | |
|---|---|---|---|---|---|---|---|
| | | SR | S | R | SR– | SR | S |
| Form 35 | R | 15 | 26 | 23 | 13 | 8 | 0 |
| | SR– | 25 | 16 | 11 | 10 | 19 | 2 |
| | SR | 3 | 16 | 0 | 0 | 3 | 16 |
| Form 36 | R | 14 | 20 | | | | |
| | SR– | 12 | 10 | | | | |
| | SR | 20 | 13 | | | | |
| | S | 2 | 18 | | | | |
| Form 49 | R | 28 | 38 | 34 | 21 | 16 | 0 |
| | SR– | 17 | 1 | 2 | 1 | 14 | 1 |
| | SR | 1 | 15 | 0 | 0 | 2 | 14 |
| | S | 0 | 3 | 0 | 0 | 0 | 3 |
| Form 52 | R | 25 | 39 | 37 | 21 | 11 | 0 |
| | SR– | 5 | 0 | 0 | 1 | 4 | 0 |
| | SR | 11 | 1 | 0 | 0 | 12 | 0 |
| | S | 2 | 18 | 0 | 0 | 3 | 17 |
| Form 57 | R | 46 | 40 | 36 | 22 | 32 | 0 |
| | S | 0 | 16 | 0 | 0 | 2 | 14 |

The figures given in the left hand section of table 3 show the effect of the factors governing the reaction to form 21 on the reactions to forms 35, 36, 49, 52, and 57. It appears that the factor, or factors, which confers on any line semi-resistance to form 21 also confers upon that line resistance or semi-resistance to the other five forms. With a few exceptions, lines SR to form 21 are R or SR to the other forms. That other factors in addition to those concerned in the reaction to form 21 are operative is indicated by the fact that large numbers of lines are resistant to forms 35, 36, etc., in spite of their susceptibility to 21. This is well illustrated in the case of form 57. All lines SR to form 21 are R to form 57; but of the fifty-six lines S to form 21, forty are R to form 57. In brief, then, the data presented in table 3 suggest that the reactions to forms 35, 36 49, 52, and 57 are governed by the same genetic factors; and further that the reactions to these forms are affected by the factors which govern the reaction to form 21.

The relationship between the reactions to form 21 and the reactions to forms 14, 15, 29, 30, 48, and 53 is illustrated by the data in table 4. In the case of form 29 and also of form 30 there is practically perfect coincidence with the reaction to form 21. The one line SR to form 21 and S

to form 29 was marked "light" to form 29 on the record card, and is, therefore, probably misplaced. It will be observed that the types of reaction vary from one form to another, even though the reactions to such forms may be governed by the same factors. Further evidence bearing on this point will be given in a later section. In some cases minor factors affecting the reaction to one form and not to another are probably operative; as, for example, in the case of the difference between the SR and S classes of form 30.

We have seen (table 4) that there is a close positive relationship between the reactions to forms 21 and 29. In the case of forms 14 and 21 the relationship is reversed, the lines highly resistant to form 14 being, as a rule, susceptible to form 21. Since the distinction between the two types of reaction to form 14 is not very marked, it was sometimes difficult to be certain of the classification. It is not improbable, therefore, that the five lines SR to form 21 and R to form 14, and the three lines S to form 21 and SR– to form 14 are wrongly classified. Marquis is susceptible

TABLE 4.—*Number of lines in each infection class of form 21 and of forms 14, 15, 29, 30, 48, and 53 in the cross Marquis × H-44-24.*

| | | Form 21 | |
|---|---|---|---|
| | | SR | S |
| Form 14 | R | 5 | 51 |
| | SR– | 38 | 3 |
| Form 15 | SR | 45 | 12 |
| | S | 2 | 38 |
| Form 29 | SR | 41 | 0 |
| | S | 1 | 52 |
| | R | 30 | 0 |
| Form 30 | SR | 0 | 29 |
| | S | 0 | 4 |
| | R | 13 | 48 |
| Form 48 | SR– | 2 | 7 |
| | SR | 24 | 2 |
| Form 53 | R | 1 | 43 |
| | SR– | 45 | 9 |

to 21 and highly resistant to 14. H-44-24 is semi-resistant to 21 and moderately resistant to 14. The relationship between the reactions of the hybrids to these two forms indicates that in this cross the high resistance of Marquis to form 14 is governed by the factor, or factors, which is concerned in its susceptibility to form 21. These results are in agreement with those obtained by Goulden *et al* (*3*), who concluded that it was impossible to combine the high resistance of Marquis to form 14 with the semi-resistance of H-44-24 to form 21. While this is a fact of considerable interest, particularly from a physiological point of view, it is of no practical importance, since the SR– reaction to form 14 characteristic of H-44-24, which is alternative to the high resistance of Marquis (no susceptible

lines being obtained) may be considered a fairly satisfactory resistance. This becomes evident from an inspection of figure 2 showing the reactions to form 53, which are practically identical with the form 14 reactions.

Figure 2. Reactions of parents and hybrids to form 53 in the cross Marquis × H-44-24. Left to right: H-44-24, SR-, R, Marquis.

Forms 15, 48, and 53 also belong to this group. The reaction to form 15 shows the same relation to the 21 reaction as does that to form 29, while 48 and 53 tend to give the same reactions as does form 14. The results with these three forms are not very clear, probably on account of the difficulty encountered in classification. It seems probable that the reactions to forms 14, 15, 21, 29, 30, 48, and 53 are governed by the same genetic factors. It is true that in several cases the coincidence of the reactions is far from complete, which suggests that the results might be explained on a linkage basis. However, some errors were certainly made in the classification of the material, so that complete agreement cannot be expected.

There are still three forms to be considered in this cross, namely, 27, 33, and 50. The relation between the reactions to these forms and the reaction to form 36 is illustrated by the figures in the right hand section of table 5. The reaction to form 36 is evidently very closely correlated with the reactions to the three other forms. We have already seen (table 3) that forms 35, 49, etc., belong to the form 36 group; why then erect a third group for the accommodation of forms 27, 33, and 50? The reason for this is found in the fact that the form 21 factors have no apparent effect upon the reactions to these three forms as they have upon the reactions to forms 36, 35, 49, etc. This is evidenced by the figures in the left hand section of table 5. Apparently the reactions to forms 27, 33, and 50 are controlled by one or more of the factors which operate in the

case of form 36. It is evident that there are no factors giving high resistance to form 36 which do not also operate in the reactions to form 27, etc., since all lines resistant to form 36 are resistant or moderately resistant to the other three forms. We have already seen, however, that the factors which govern the reaction to form 21 are chiefly concerned in differences between semi-resistance and susceptibility. The close positive relationships shown in the right hand section of table 5 do not, therefore, conflict with the view that the form 21 factors are operative in the reaction to form 36, but without effect on the reactions to forms 27, etc.

TABLE 5.—*Number of lines in each infection class of forms 21 and 36 and of forms 27, 33, and 50, in the cross Marquis × H-44-24.*

| | | Form 21 | | Form 36 | | | |
|---|---|---|---|---|---|---|---|
| | | SR | S | R | SR– | SR | S |
| Form 27 | R | 28 | 41 | 36 | 23 | 13 | 0 |
| | SR | 17 | 15 | 0 | 0 | 18 | 14 |
| Form 33 | R | 26 | 39 | 35 | 23 | 12 | 0 |
| | SR– | 0 | 12 | 1 | 0 | 5 | 8 |
| | SR | 18 | 8 | 0 | 0 | 16 | 10 |
| Form 50 | R | 13 | 25 | 18 | 16 | 7 | 0 |
| | SR– | 12 | 19 | 16 | 5 | 7 | 5 |
| | SR | 14 | 14 | 0 | 0 | 14 | 14 |

According to the results with this cross the fifteen physiologic forms fall into three fairly well defined groups, as arranged in figure 3. The results may be explained on the basis of two sets (one or more pairs in each) of genetic factors, one set affecting the reaction to the forms of groups I and II, and the other set affecting the reaction to the forms of groups I and III. These two sets of factors are represented by the letters B and A respectively in figure 3. The reactions to forms belonging to group II are mainly, if not solely, governed by the B set of factors, though the possibility of the operation of minor modifiers is not excluded. The reactions to forms of group I are affected by both sets of factors, and the reactions to the forms of group III are apparently controlled by the A set.

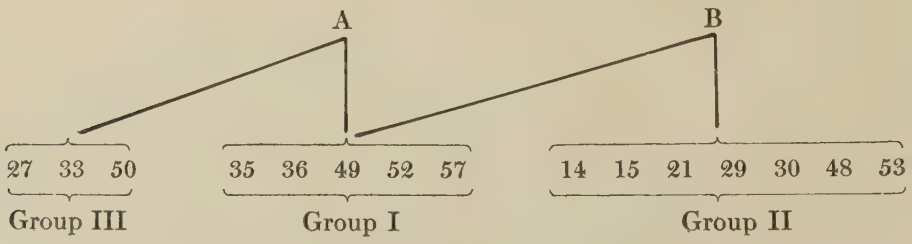


Figure 3. Diagrammatic representation of factor relations in the cross Marquis × H-44-24.

The data presented here afford no clue to the actual number of factor pairs concerned. However, a consideration of the results of Goulden *et al* (*3*) throws some light on this question. Their results indicate that in the

cross Marquis × H-44-24 the reaction to form 21 is governed by one or two pairs of factors. They found the inheritance of the reaction to form 36 to be controlled by two factors. The actual results are given in table 6, which is reproduced from their paper.

TABLE 6.—*Numbers of $F_3$ families, homozygous resistant, segregating, and homozygous susceptible to form 36, and calculation of goodness of fit to a theoretical 3:12:1 ratio.*

| Groups | Actual | Theor. (3:12:1) | $(A-T)^2/T$ |
|---|---|---|---|
| Hom. R+ SR | 148 | 139.7 | .49 |
| Segregating | 548 | 558.7 | .20 |
| Hom. S | 49 | 46.6 | .12 |
| Totals | 745 | 745.0 | .81=$\chi^2$ |

Since all lines in the present study (with a few exceptions) semi-resistant to form 21 are likewise resistant or semi-resistant to form 36 and others, there are probably no factors giving semi-resistance to form 21 which do not also operate in the reactions to form 36 and other forms of group I. Now certainly the reactions to the forms of groups I and III are affected by one or more factors which do not affect the reactions to forms of group II (see discussion of table 3). Therefore if only two pairs of factors are concerned in the reaction to form 36, as the results of Goulden *et al* indicate, only one of which can be concerned in the reaction to form 21, the main differences in reaction to the fifteen forms studied must be controlled by two factors. Such an explanation does not, of course, exclude the possibility of minor factors modifying the reaction to certain forms. In discussing the relation between the reactions to forms 35 and 36 (see table 3) it was suggested that the difference between semi-resistance and susceptibility to form 36 might be controlled by a factor which did not operate in the reaction to form 35, no lines being completely susceptible to the latter form. In view of the facts brought out in the foregoing discussion it is much more probable that the reactions to forms 35 and 36 are controlled by the same factors. As previously suggested, the absence of a susceptible class in the case of form 35 may indicate that this form is rather less virulent on H-44-24 × Marquis hybrids than is form 36.

The general conclusions may be briefly summarized by taking forms 36, 21, and 33 as representatives of groups I, II, and III respectively. Using the symbols A and B, as in figure 3, to represent the two factor pairs concerned, we obtain the following result:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| AABB | = | R | 36 | R | 33 | SR | 21 |
| AAbb | = | R | 36 | R | 33 | S | 21 |
| aaBB | = | SR | 36 | SR | 33 | SR | 21 |
| aabb | = | S | 36 | SR | 33 | S | 21 |

Thus the possession of the factor A by a given line confers upon that line resistance to forms 36 and 33, and the presence of the factor B confers on any line which carries it, semi-resistance to forms 21 and 36.

This is simply a restatement of the conclusions drawn from tables 3 and 5, and illustrated in figure 3.

*Marquillo × H-44-24*

The variety Marquillo inherits the high resistance of Iumillo to several physiologic forms, and it is less susceptible than Marquis to several others. It is, therefore, not surprising that the results obtained in this cross are quite different from those of the cross Marquis × H-44-24.

Forms 14 and 21 stand alone in this cross, being the only forms used which have infection capabilities governed by one set (one or more pairs) of factors. The relation between the reactions to these two forms is quite different from that found in the case of Marquis × H-44-24. In the latter cross the moderate resistance of H-44-24 to form 14 is alternative to the high resistance of Marquis. Marquillo is also highly resistant to form 14, but this resistance is not alternative to the resistance of H-44-24. This is clearly shown by the data in table 7, since there are thirty-six lines susceptible to form 14. It is equally clear that the semi-resistance of H-44-24 to form 21 is not alternative to the high resistance of Marquillo, since there are eighty-six lines susceptible to form 21. It appears probable from the distribution of lines as shown in the table, that the resistance of Marquillo to these two forms is governed by the same genetic factors. Of the fifty-nine lines resistant to form 21 none are susceptible to form 14, and of the forty-four lines resistant to form 14, only two are recorded as susceptible to form 21. The semi-resistant classes in both cases are, in all probability, a result of the operation of the factors carried by H-44-24 for partial resistance to these two forms. The two lines which are susceptible to form 21 and resistant to 14 are probably misplaced as a result of errors in classification. These two forms constitute group I.

TABLE 7.—*Number of lines in each infection class of forms 14 and 21 in the cross Marquillo × H-44-24.*

| | | Form 14 | | | |
|---|---|---|---|---|---|
| | | R | SR– | SR | S |
| Form 21 | R | 40 | 7 | 12 | 0 |
| | SR | 2 | 2 | 11 | 3 |
| | S | 2 | 11 | 40 | 33 |

The next group which will be discussed consists of forms 27, 30, 33, 35, 36, 48, 49, 50, 52, and probably 57. The results with form 57 are somewhat uncertain, due, probably, to the difficulty which was encountered in effecting a satisfactory classification. Resistance to all these forms appears to be governed by the same factors. In other words, any line of this cross resistant to one of these forms will be resistant or semi-resistant to all others, and any line susceptible to one form will be susceptible, or at best semi-resistant, to all others of this group. The data in the right hand section of table 8 illustrate the close relationships between the infective capabilities of the forms of this group. In most cases the reaction to form 36 is very closely correlated with the reactions to the other forms. The results are rather more significant than those

obtained in the cross Marquis × H-44-24, since about twice as many hybrid lines were used for the study of each physiologic form.

As pointed out in a previous section, it must not be supposed that because the same genetic factors govern the reactions to all these forms, that all forms are characterized by the same type of reaction on the lines of this cross. As a matter of fact the differences are striking, and illustrate in an interesting manner the specificity of the physiologic forms and the complexity of their relationships with different strains of wheat. A comparison between the reactions to forms 52 and 33 will serve to illustrate this point. We have seen (table 8) that the reactions to form 52 were classified as R, SR–, SR, and S. These types are illustrated in figure 4.

TABLE 8.—*Number of lines in each infection class of forms 21 and 36, and of several other forms in the cross Marquillo × H-44-24.*

| | | Form 21 | | | Form 36 | | |
|---|---|---|---|---|---|---|---|
| | | R | SR | S | R | SR | S |
| Form 27 | R | 54 | 8 | 46 | 94 | 14 | 4 |
| | SR | 10 | 12 | 44 | 21 | 23 | 22 |
| | S | 0 | 1 | 6 | 0 | 4 | 3 |
| Form 30 | R | 32 | 7 | 39 | 75 | 4 | 0 |
| | SR– | 11 | 3 | 17 | 19 | 8 | 3 |
| | SR | 5 | 5 | 10 | 7 | 7 | 7 |
| | MS | 0 | 2 | 4 | 0 | 2 | 4 |
| | S | 0 | 2 | 11 | 1 | 1 | 11 |
| Form 33 | R | 65 | 12 | 60 | 119 | 22 | 0 |
| | SR– | 5 | 8 | 40 | 4 | 14 | 34 |
| | SR | 0 | 0 | 2 | 0 | 0 | 2 |
| Form 35 | R | 43 | 9 | 51 | 98 | 6 | 0 |
| | SR– | 17 | 4 | 16 | 23 | 9 | 5 |
| | SR | 6 | 7 | 26 | 3 | 20 | 19 |
| | S | 0 | 2 | 5 | 0 | 3 | 4 |
| Form 36 | R | 62 | 9 | 62 | | | |
| | SR | 14 | 13 | 10 | | | |
| | S | 0 | 4 | 40 | | | |
| Form 48 | R | 35 | 7 | 15 | 49 | 9 | 1 |
| | SR– | 19 | 6 | 51 | 48 | 15 | 12 |
| | SR | 7 | 7 | 24 | 12 | 13 | 12 |
| | MS | 1 | 2 | 6 | 0 | 5 | 6 |
| Form 49 | R | 64 | 9 | 47 | 105 | 14 | 0 |
| | SR– | 10 | 8 | 20 | 20 | 20 | 2 |
| | SR | 0 | 5 | 36 | 2 | 10 | 28 |
| Form 50 | R | 38 | 7 | 47 | 89 | 4 | 0 |
| | SR– | 14 | 3 | 15 | 23 | 7 | 0 |
| | SR | 14 | 6 | 19 | 6 | 24 | 12 |
| | S | 0 | 6 | 23 | 0 | 10 | 19 |
| Form 52 | R | 37 | 5 | 20 | 63 | 0 | 0 |
| | SR– | 13 | 4 | 36 | 48 | 5 | 0 |
| | SR | 14 | 8 | 14 | 7 | 20 | 12 |
| | S | 2 | 7 | 22 | 0 | 9 | 23 |
| Form 57 | R | 58 | 16 | 71 | 115 | 25 | 6 |
| | SR | 6 | 5 | 5 | 3 | 9 | 5 |
| | S | 0 | 1 | 12 | 0 | 0 | 13 |

We have seen also that the reactions to form 52 are governed by the same factors as those operating in the case of 36. That the reactions to form 33 are likewise dependent upon the same factors is indicated by the figures in table 8 but with form 33 the distinction is only between R, SR–, and SR. There are only two lines in the SR class, and it is possible that they are a result of natural crossing. However, the reactions illustrated in figure 5 show that the factors concerned originate from at least three different sources, namely, Yaraslov emmer (H-44-24 being more highly resistant than Marquis), Iumillo, and Marquis. It will be observed that the SR– reaction is practically identical with that of Marquis. Results obtained with form 33 in the cross Marquis × H-44-24 showed that the H-44-24 resistance was not alternative to the Marquis resistance. Consequently in this cross (Marquillo × H-44-24) at least three pairs of factors must be in operation, and a paucity of SR lines is not surprising. Two of the four lines classified as R to 36 and SR– to 33 were queried on the record card, and it is probable that all four are misplaced. These results show that the same genetic factors condition differences between R, SR, and S to form 36; R, SR– SR, and S to form 52; and R, SR–, and SR in the case of form 33.

The factors concerned in the reactions to forms 14 and 21 (group I) are operative in this group. The data in the left hand section of table 8 illustrate this fact quite clearly. The lines resistant to form 21 are resistant to all forms of this group, except for the forms 48 and 52, for which one and two lines respectively are recorded as being susceptible. That factors in addition to those concerned in the reaction to form 21 are operative in this group is evidenced by the fact that in all comparisons there are a large number of lines which are susceptible to form 21, but resistant to the other forms. It appears evident, therefore, that the factors which govern the reaction to form 36 in this cross also govern the reaction to nine of the other thirteen forms studied. The reactions to the forms of this group (group II) are controlled by the factors which govern the reactions to the forms of group I plus one or more pairs of additional factors.

Two other forms were used in the study of this cross, namely, 29 and 53. In the case of 53 considerable difficulty was encountered in classification. However, an effect of the factors concerned in the reactions to the forms of group I was apparent.

TABLE 9.—*Number of lines in each infection class of forms 21 and 29 in the cross Marquillo × H-44-24*

| | | Form 29 | | |
|---|---|---|---|---|
| | | SR | MS | S |
| Form 21 | R | 44 | 9 | 0 |
| | SR | 7 | 5 | 6 |
| | S | 22 | 25 | 28 |

The results obtained with form 29 are of considerable interest. The figures in table 9 show the effect of the factors which are responsible for resistance to form 21, no lines carrying these factors being susceptible

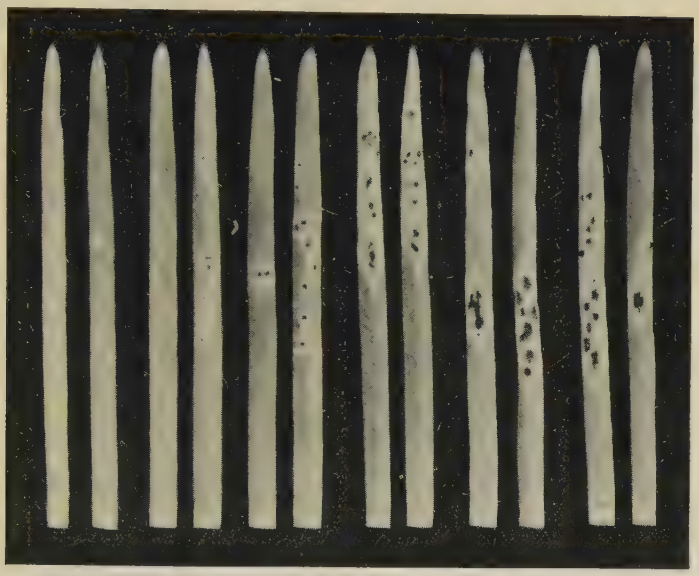

Figure 4. Reactions of parents and hybrids to form 52 in the cross Marquillo × H-44-24. Left to right: H-44-24, R, SR-, SR, S, Marquillo.

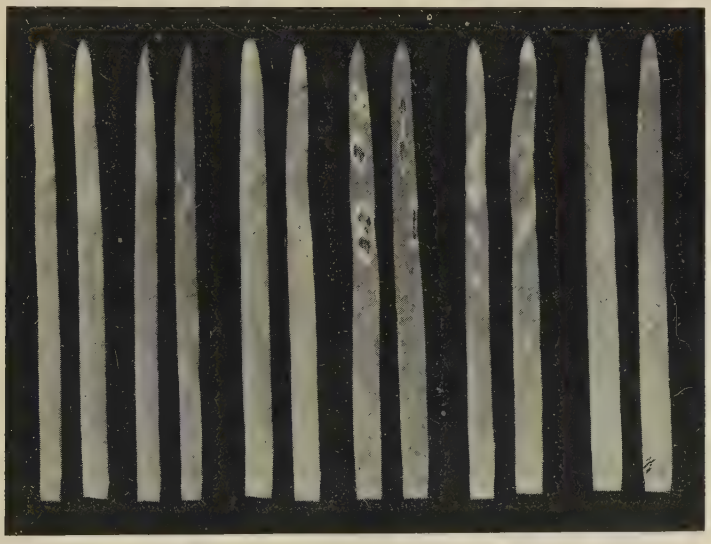

Figure 5. Reactions of parents and hybrids and the variety Marquis to form 33 in the cross Marquillo × H-44-24. Left to right: H-44-24, R, SR-, SR, Marquis, Marquillo.

to form 29. Since twenty-two lines are semi-resistant to form 29 and susceptible to form 21, additional factors must be in operation. A consideration of the figures in table 10 suggests that the additional factors are not those concerned in the reaction to form 36, and hence the other forms of group II, since there are twenty-three lines resistant to 36 and susceptible to 29. However, it must be borne in mind that the reactions

to the forms of group II are controlled by several pairs of factors. It is quite possible that one or more of the group II factors affect the reaction to form 29, while others are without effect. This would allow a certain number of lines to be resistant to form 36 and susceptible to form 29. It is also possible that a third set of factors which is concerned with neither the reactions to forms of group I or of group II operates in the case of form 29. The relationship is by no means simple, and cannot be definitely explained from the data presented. Form 29 cannot be placed in group I or group II, since the reactions of the hybrid lines to this form are not the same as those to either form 21 (group I) or form 36 (group II). Hence it is tentatively suggested that a third set of factors is involved.

TABLE 10.—*Number of lines in each infection class of forms 29 and 36 in the cross Marquillo × H-44-24.*

| | | Form 29 | | |
|---|---|---|---|---|
| | | SR | MS | S |
| Form 36 | R | 50 | 23 | 23 |
| | SR | 19 | 5 | 1 |
| | S | 7 | 11 | 10 |

In brief, the results indicate that in this cross the reactions to forms 14 and 21 are governed by the same genetic factors. It is evident that the factors for resistance to forms 21 and 14 confer upon lines bearing them resistance or semi-resistance to all forms studied. A second set of factors is operative in the reactions to forms 27, 30, 33, 35, 36, 48, 49, 50, 52, and 57. The reaction to form 29 is affected by the factors concerned in the reactions to the two forms of group I plus a set of factors which may or may not be identical with one or more pairs of the group II factors. These conclusions are illustrated diagrammatically in figure 6 where the letters A, B, and C represent the three sets of genetic factors.

The data afford no clue to the actual number of factor pairs involved, except that the results with form 33 indicate the operation of at least three pairs in the reactions to this and other forms of group II.

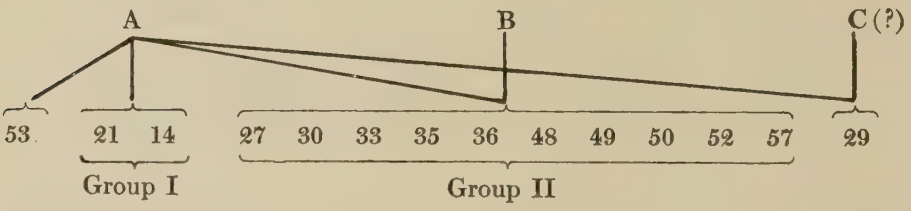


Figure 6. Diagrammatic representation of the factor relations in the cross Marquillo × H-44-24.

*Garnet × Double Cross*

The variety Double Cross inherits immunity to several physiologic forms from Kanred. As noted in an earlier section, Aamodt (*1*) demonstrated that the inheritance of the immunity of Kanred to several

physiological forms was governed by a single pair of factors. Double Cross possesses the immunity of Kanred to eight of the eleven forms used in connection with this cross. The results obtained agree with Aamodt's data in that a line immune to any one of these eight forms is immune to all. The factor pair which governs this immunity has no apparent effect on the reactions to other forms to which Kanred is not immune; its effect appears to be restricted to the immune reaction. For this reason lines characterized by immune reactions are omitted from the tables.

The variety of types of reaction which appeared in this cross, together with the fact that the susceptibility of Garnet was in several cases not recovered, suggests the operation of a large number of factors. Indeed this is to be expected because Double Cross carries factors for resistance tracing to Marquis, Kanred, and Iumillo. For example, in the case of form 14, besides immunity, the high resistance of Iumillo, the Marquis resistance (cf. also figure 2; the reaction of Marquis to form 14 is identical with that to 53), an intermediate type, and Garnet susceptibility all appeared.

Unfortunately nearly half of the lines selected for study carried the factor pair concerned in the Kanred immunity. As a result a relatively small number of lines was available for the study of other reactions, except in the case of forms 33, 35, and 36, to which Kanred (and consequently Double Cross) is not immune. Accordingly the results with this cross are none too satisfactory, though highly suggestive.

The first group we shall consider contains forms 21, 29, 30, 36, and 49. In spite of the small number of lines, the evidence for the reactions being governed by the same factors is very satisfactory. The figures in table 11 show the general type of relationship. It is interesting that the forms of this group are distributed among three groups in the Marquillo × H-44-24 cross (see figure 6). In order to emphasize again that forms belonging to the same group may be characterized by different reactions, the infection types of forms 29 and 49 are shown in figures 7 and 8.

TABLE 11.—*Number of lines in each infection class of form 21 and other forms of group I in the cross Garnet × Double Cross.*

| | | Form 21 | | |
|---|---|---|---|---|
| | | R | SR | S |
| Form 29 | SR | 7 | 7 | 0 |
| | MS | 2 | 9 | 9 |
| | S | 0 | 2 | 4 |
| Form 30 | SR | 8 | 0 | 0 |
| | MS | 0 | 3 | 0 |
| | S | 0 | 21 | 19 |
| Form 36 | R | 6 | 0 | 0 |
| | SR | 5 | 16 | 0 |
| | S | 0 | 10 | 19 |
| Form 49 | R | 8 | 0 | 0 |
| | SR- | 2 | 2 | 0 |
| | SR | 0 | 20 | 10 |
| | MS | 0 | 2 | 6 |
| | S | 0 | 0 | 3 |

The coincidence between the reactions to the forms of this group is quite striking, and there is little doubt that the reactions to all five forms are governed by the same factors.

The second group contains forms 35 and 48. Since segregating lines and those immune to 48 are not considered, the numbers are rather small. The relationship between the reactions to these two forms is illustrated by the data contained in table 12. It appears very probable that the same factors govern the reactions to both forms. It is noteworthy that the susceptibility of Garnet was not recovered in either case. These two forms constitute group II.

TABLE 12.—*Number of lines in each infection class of forms 35 and 48 in the cross Garnet × Double Cross.*

| | | Form 48 | | |
|---|---|---|---|---|
| | | R | SR– | SR |
| Form 35 | R | 17 | 0 | 1 |
| | SR | 1 | 10 | 4 |

The two forms 14 and 33 of which group III is composed are of considerable interest. The group has no set of factors peculiar to itself, but the reactions are affected by both sets of factors which are concerned in the reactions to the forms of groups I and II. That the reactions to these two forms are governed by the same factors is indicated by the figures in table 13. In view of the small number of lines the relationship, though indicated, is by no means established.

Figure 7. Reactions of hybrids to form 29 in the cross Garnet × Double Cross. Left to right: O, SR, MS, S.

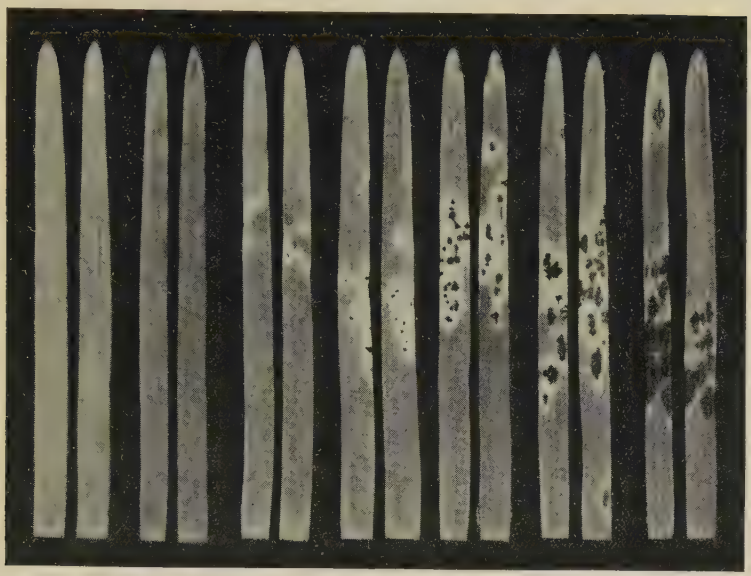

Figure 8. Reactions of parents and hybrids to form 49 in the cross Garnet × Double Cross. Left to right: Double Cross, O, R, SR-, SR, MS, Garnet. (The S reaction, which is not included, was similar to that of Garnet.)

TABLE 13.—*Number of lines in each infection class of forms 14 and 33 in the cross Garnet × Double Cross.*

| | | Form 14 | | | |
|---|---|---|---|---|---|
| | | R | SR– | SR | MS |
| Form 33 | R | 16 | 0 | 0 | 0 |
| | SR– | 4 | 4 | 0 | 0 |
| | SR | 1 | 1 | 1 | 0 |
| | MS | 0 | 0 | 0 | 2 |

The effect of the factors which control the reactions to the forms of group I is shown by the relation between the reactions to form 21 and the two forms of group III (see table 14). Since eight lines are resistant to form 14 and susceptible to form 21, and a similar number in the case of form 33 are resistant in spite of being susceptible to form 21, the action of other factors besides those concerned in the reaction to form 21 is indicated. That the additional factors concerned are those which govern the reactions to forms of group II is suggested by the relationship between the reactions to forms 35 and 14 (see table 15). An effect of the factors which govern the reaction to form 35 is strongly suggested, though the number of lines is too small to allow of very definite conclusions being drawn.

The two other forms that were used in the study of this cross, 50 and 53, occupy a rather isolated position: neither of the two sets of factors associated with resistance to the forms of groups I, II and III (see figure 9) are effective with these two. There was some evidence that the same factors were involved in the reactions to these two forms, but it was

very slender. Figure 9 illustrates the probable factor relations in this cross. The letters A and B represent sets of genetic factors. The A set is operative in the reactions to the forms of groups I and III, and the B set is concerned in the reactions to the forms of groups II and III. The data afford no clue to the actual number of factor pairs involved.

TABLE 14.—*Number of lines in each infection class of form 21 and the two forms of group III in the cross Garnet × Double Cross.*

| | | Form 21 | | |
|---|---|---|---|---|
| | | R | SR | S |
| Form 14 | R | 8 | 11 | 8 |
| | SR– | 0 | 4 | 4 |
| | SR | 0 | 0 | 1 |
| | MS | 0 | 2 | 2 |
| Form 33 | R | 5 | 11 | 8 |
| | SR– | 1 | 7 | 3 |
| | SR | 0 | 2 | 1 |
| | MS | 0 | 2 | 0 |

TABLE 15.—*Number of lines in each infection class of forms 14 and 35 in the cross Garnet × Double Cross.*

| | | Form 14 | | | |
|---|---|---|---|---|---|
| | | R | SR– | SR | MS |
| Form 35 | R | 12 | 0 | 0 | 0 |
| | SR | 9 | 5 | 1 | 2 |

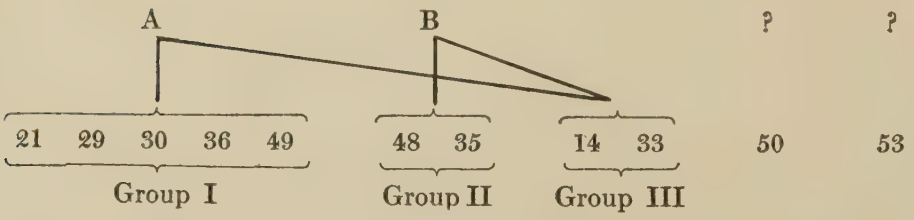


Figure 9. Diagrammatic representation of the factor relations in the cross Garnet × Double Cross.

## FIELD REACTIONS

The purpose of this part of the investigation was that of determining the effect, if any, of the factors concerned in the reaction of seedlings in the greenhouse on the resistance to stem rust under field conditions. Due to a combination of poor soil and adverse weather conditions, many lines failed to make a good stand. However, on those lines that did thrive an excellent epidemic of stem rust was obtained, and in spite of being based on relatively few lines, the results are of considerable interest and significance.

Goulden *et al* (*3*) have shown that the factors governing the greenhouse reaction in the seedling stage to forms 36 and 21 in lines of the cross Marquis × H-44-24 have no apparent effect on the field reaction.

The high field resistance of H-44-24 was inherited quite independently of the greenhouse reactions. The results of the present study show that resistance to forms 36 and 21 involves resistance to at least thirteen other forms, in the same cross. The obvious inference is that lines susceptible in the seedling stage in the greenhouse to the fifteen forms used have as good a chance of being resistant in the field as have lines resistant to the fifteen forms in the greenhouse. In other words, selection on the basis of seedling reaction in the greenhouse is useless as far as the cross Marquis × H-44-24 is concerned.

The field results of the present study are in agreement with this viewpoint, though the number of lines for which field determinations were made is very small. Table 16 shows that the A factor (see figure 3) represented by the reaction to form 21, is quite ineffective as far as field resistance is concerned. That the B factor, represented by the reaction to form 36, is also ineffective is shown by the figures in table 17.

TABLE 16.—*Relation between the seedling reaction to form 21 in the greenhouse, and the field reaction in the cross Marquis × H-44-24.*

| | | Field Reaction | | | |
|---|---|---|---|---|---|
| | | R | MS | S | Seg. |
| Form 21 | SR | 11 | 4 | 8 | 3 |
| | S | 10 | 8 | 6 | 10 |

TABLE 17.—*Relation between the seedling reaction to form 36 and the field reaction in the cross Marquis × H-44-24.*

| | | Field Reaction | | | |
|---|---|---|---|---|---|
| | | R | MS | S | Seg. |
| Form 36 | R | 12 | 6 | 4 | 11 |
| | SR | 5 | 5 | 7 | 1 |
| | S | 4 | 3 | 2 | 3 |

Different results were obtained in the cross Marquillo × H-44-24. An effect of the factors that govern seedling resistance to the forms used is indicated. The action of the B set (see figure 6) of factors identified in connection with the greenhouse reactions is shown by the relation between the field reaction and the seedling reaction to form 36. The figures are given in table 18. The effect of the B set of factors on the R and S field classes is relatively small, but on the SR and MS classes it is more noticeable. It is not improbable that the two last named classes owe their distinction from the S class to the B factors identified in connection with the seedling reactions in the greenhouse.

TABLE 18.—*Relation between the seedling reaction to form 36 in the greenhouse, and the field reaction in the cross Marquillo × H-44-24.*

| | | Field Reaction | | | | |
|---|---|---|---|---|---|---|
| | | R | SR | MS | S | Seg. |
| Form 36 | R | 32 | 8 | 13 | 24 | 33 |
| | SR | 12 | 1 | 3 | 7 | 9 |
| | S | 10 | 0 | 2 | 18 | 8 |

The data in table 19 show the relation between the greenhouse reaction to form 21 and the field reaction, or in other words, the effect of the A set of factors on the field reaction.

TABLE 19.—*Relation between the seedling reaction to form 21 in the greenhouse and the field reaction in the cross Marquis × H-44-24.*

| | | Field Reaction | | | | |
|---|---|---|---|---|---|---|
| | | R | SR | MS | S | Seg. |
| Form 21 | R | 26 | 6 | 11 | 5 | 15 |
| | SR | 7 | 1 | 2 | 9 | 4 |
| | S | 20 | 1 | 5 | 36 | 31 |

In this case there is a well marked relationship. Of the fifty lines susceptible in the field, only five were resistant to form 21, and of the fifty-three lines that were resistant in the field, twenty-six were resistant in the greenhouse. Evidently the factors responsible for resistance to form 21 in the greenhouse have a marked effect on the field reaction. The combined action of the A and B sets of factors is shown by the data in table 20. Sixteen of the twenty lines that were susceptible in the field were susceptible to forms 21 and 36 in the seedling stage in the greenhouse, and of the twenty-seven lines that were resistant in the field, nineteen were resistant to forms 21 and 36 in the seedling stage. The eight lines that were resistant in the field and susceptible to both forms 21 and 36 in the greenhouse, undoubtedly owe their resistance to the factors that govern the mature plant resistance of H-44-24. The positive relationship between field and greenhouse resistance found in this cross must be largely, or solely, due to the resistance of Marquillo.

TABLE 20.—*Relation between the reactions to forms 21 and 36 in the greenhouse, and the field reaction in the cross Marquillo × H-44-24.*

| | Field Reaction | | | | |
|---|---|---|---|---|---|
| | R | SR | MS | S | Seg. |
| R to 36 & 21 | 19 | 6 | 11 | 4 | 13 |
| S to 36 & 21 | 8 | 0 | 2 | 16 | 8 |

The results obtained from the field study of the cross Garnet × Double Cross indicate that the factors concerned in the seedling reactions in the greenhouse do affect the field reactions. The degree of the relationship between the field and greenhouse reactions cannot be determined from the relatively small amount of data at hand. The figures in table 21 show that the factor pair which governs the immunity of Kanred (possessed also by Double Cross) is practically ineffective as far as field resistance is concerned, when other forms to which Kanred is susceptible are present. This is to be expected, since it is well known that lines bearing the factor pair which governs the immunity of Kanred may be completely susceptible to other forms. Several Kanred susceptible forms were certainly included in the field epidemic. It is of some

significance, perhaps, that the four most resistant lines (40 per cent in the field) possessed the immunity factor.

TABLE 21.—*Relation between the immunity of seedlings to certain physiologic forms and the field reaction in the cross Garnet × Double Cross.*

| | | Field Reaction (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 40 | 50 | 60 | 70 | 80 | 90 | Mean |
| Greenhouse Reaction | O | 4 | 1 | 1 | 3 | 13 | 7 | 74.1 |
| | R to S | 0 | 3 | 2 | 7 | 16 | 3 | 74.5 |

The combined effect of the A and B sets of factors (see figure 9) identified in the greenhouse studies with this cross is shown by the relationship of the greenhouse reactions to forms 33, 35 and 36 with the field reaction (see table 22). There is practically no evidence of the operation of any factors in addition to those identified with the seedling reactions in the greenhouse. It is true that the numbers are small and one line resistant to no forms in the greenhouse was resistant in the field; nevertheless, the lines showing resistance to none of the three forms representative of the greenhouse reactions are concentrated in the susceptible field reaction classes. More extensive field data are necessary before any definite conclusions can be drawn with regard to the effect of the factors identified in the greenhouse on the field reactions.

TABLE 22.—*Relation between the seedling reaction to forms 33, 35, and 36 in the greenhouse and the field reaction in the cross Garnet × Double Cross.*

| | Field Reaction (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 40 | 50 | 60 | 70 | 80 | 90 | Mean |
| R to all of 33, 35, 36. | | | none obtained | | | | |
| R " 2 " " " " | 1 | | 2 | 5 | 8 | | 72 |
| R " 1 " " " " | 1 | 2 | 1 | | 4 | 1 | 68 |
| R " none " " " " | | 1 | | 2 | 15 | 9 | 81 |

## DISCUSSION

When the results of the above investigation are considered in relation to the work mentioned in the introductory part of this paper, some very significant facts become clear. The "group" of physiologic forms identified by Goulden *et al* (*3*) in the cross between Marquis and H-44-24 is undoubtedly limited by the same factors as is group II described here. Three of the forms, 14, 15, and 21 are the same, and forms 9, 17, and 34 were not included in this study. This means that the three last named forms may be added to group II, thus increasing the number in this group to ten. Since the reactions to all forms of groups I and II are affected by the A pair of factors, the total number of forms affected is increased from twelve to fifteen; yet this pair of factors has little or no effect on the field reaction.

Passing to the crosses Marquillo × H-44-24 and Garnet × Double Cross, we find a very different grouping of the forms. This is to be

expected in view of the fact that apparently closely related wheat varieties may be resistant to very different groups. Variety A may be resistant to some forms to which B is resistant, and variety C may be resistant to only a few of the A and B resistant forms, and resistant to some to which A or B or both, are susceptible. This means that even if the identification of groups such as those described here might be of value from a breeding point of view (which is very doubtful), the grouping would have to be worked out anew for all hitherto unexplored crosses in which the breeder might be interested. It is true that in two of the three crosses studied, the factors identified in the greenhouse did influence the field reaction, particularly in the case of Marquillo × H-44-24. However, this is of less importance than it may appear to be. A large measure of success has been attained in combining the resistance of a Marquis × Kanred hybrid with that of Marquillo (see Hayes *et al* (*11*)). From a comparative study of several crosses, Neatby and Goulden (*13*) have shown that the mature plant resistance of Hope and H-44-24 is much more simply inherited than is the Marquillo resistance. Recent studies (unpublished) conducted by Dr. Hayes and his associates at the Minnesota Agricultural Experiment Station agree, in general, with these findings. Regardless of the number and variety of physiologic forms included in the field epidemic, Hope and H-44-24 have continued highly resistant in the field both at Winnipeg and at the various stations in Minnesota and North Dakota. If this resistance continues effective, and if it can be combined with the necessary qualities of a good bread wheat—and the evidence is strongly in favour of both these conditions being fulfilled, Goulden (*2*) — then greenhouse studies of reaction to specific forms have no place in the practical breeding program. The breeder and grower are not concerned with the number of physiologic forms which may attack seedlings of a variety in the greenhouse, if that variety is resistant under field conditions. The number of physiologic forms originated by natural and artificial means now reaches more than one hundred; but none, so far as is known, can attack varieties characterized by the so-called "mature plant" resistance in the field. There is probably no cause for alarm at the possibility of a much greater increase in number.

The relationship between the seedling and mature plant reaction has been studied on an extensive scale by Goulden *et al* (*5*). The fourteen varieties used fall into three groups: (1) containing the varieties Garnet, Marquis, Quality, Vernal, Khapli and Iumillo, in which there was almost perfect agreement between the seedling and mature plant reactions; (2) containing the varieties Hope, H-44-24, Pentad, Acme, and Black Persian, in which there was a decided lack of agreement between the seedling and mature plant reactions; and (3) containing the varieties Reward, Kota, and Marquillo, in which there was imperfect agreement. These results are particularly significant when considered in relation to the work of Dr. Hart (*7*), which is discussed in the following paragraph.

With regard to the actual mechanism of this mature plant resistance, very little is known. It is a very high type of resistance; in the case of Hope it approaches immunity. We know also that it is inherited in a very simple manner, and that it appears to combine readily with high

milling and baking qualities, and other important characters (see Goulden (*2*)). Hart (*7*) has suggested that this type of resistance is conditioned by stomatal behaviour, and designates it "functional" resistance. Certain varieties showing varying degrees of rust resistance in the field were found to be characterized by stomata which remained closed until a later hour in the morning than did the stomata of susceptible varieties. Dr. Hart suggests that the tardiness of the opening of the stomata permits the dew to dry off the leaves before infection can take place. However, a study of the field reaction of some of the varieties used reveals some apparent inconsistencies. The functional idea offers a very nice explanation of the resistance of the variety Hope, on which there is frequently no sign of infection though the epidemic may be heavy on other nearby varieties. On the other hand Webster and Khapli, both of which are characterized by tardy opening of the stomata, according to Dr. Hart, are often literally covered (Webster more frequently than Khapli) with relatively small pustules. The proposal, therefore, to consider the resistance of Hope, Webster, and Khapli as "functional" in nature is difficult to accept. These difficulties were emphasized by Goulden *et al* (*5*). In the opinion of the writer the mechanism of the mature plant resistance of Hope, Acme, etc., is still an open question.

## Summary

1. A study of the cross Marquis × H-44-24 in which the reactions to fifteen physiologic forms were studied is described. The forms fall into three groups, one containing seven, another five, and a third three forms. Two sets of factors are identified, one of which affects the reactions to the forms of groups I and II, and another which affects the reactions to forms of groups I and III. From a consideration of the results of Goulden *et al* (*3*) with the same cross, it is concluded that each of the two sets of factors consists of only one pair.

2. In the case of the Marquillo × H-44-24 cross, fourteen physiologic forms were used. One set of factors affects the reactions to all forms used, only two of which (group I) appear to be governed solely by these factors. A second set of factors affects the reactions to ten forms. These ten forms constitute group II. The reaction to form 29 is governed by the factors concerned in the reactions to the forms of group I plus additional factors which may or may not be identical with some of the second set of factors identified in connection with group II. In this cross the forms are grouped quite differently from the grouping in the cross Marquis × H-44-24. No conclusion with regard to the number of factor pairs involved can be drawn.

3. Three groups of forms are identified in the cross Garnet × Double Cross. One contains five forms, and the two others contain two each. The reactions are governed by two sets of factors, one of which affects the reactions to forms of groups I and III, and a second which affects the reactions to forms of groups II and III.

4. Experiments with regard to the effects of the factors governing the seedling reaction on the field reaction are described. In the case of Marquis × H-44-24 the field reaction is entirely independent of the seedling

reaction in the greenhouse. The factors that govern the seedling reaction in the greenhouse are expressed in the field reaction in the case of Marquillo × H-44-24. In the cross Garnet × Double Cross there is little or no evidence of any factors affecting the field reaction except those concerned in the seedling reaction in the greenhouse. The data, however, are not extensive, and the results can only be considered suggestive.

5. The bearing of studies of this kind on the problem of breeding rust resistant varieties of wheat is discussed.

## Acknowledgments

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# STOMATAL BEHAVIOR IN RELATION TO THE BREEDING OF WHEAT FOR RESISTANCE TO STEM RUST [1]

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## Introduction

The recent work of Hart (*8*) indicated that the resistance of certain wheat varieties to stem rust under field conditions may be due to the behavior of their stomata. This was termed "functional resistance" in contradistinction to the two known types of resistance, viz., physiological and morphological. This new possibility is of interest to the plant breeder, since in breeding plants for resistance to disease it is desirable to know as much as possible concerning the nature of the resistance. The object of the present study is to investigate the relationship between stem rust resistance and stomatal behaviour in wheat with particular reference to the variety known as H-44, a wheat possessing high resistance to rust and which is being widely used in plant breeding projects.

## Previous Investigations

In the breeding of wheat for resistance to stem rust, considerable attention has been paid to the resistance of various wheat varieties to different physiologic forms of rust. The rust reactions have been studied chiefly on seedlings in the greenhouse. Much of the breeding work has consisted of crossing varieties which have resistance to different groups of physiologic forms in order to produce strains of wheat which combine the disease-resisting potentialities of the parents used. With over one hundred known physiologic forms to deal with the problem is necessarily complex. Marked progress, has, however, been made. Reviews of work done in this field appear in many papers (*1*). If the wheats produced by breeding are to be of economic value they must have good quality, and this term refers to a very complex set of characters. The necessity of combining the characters of rust resistance and quality, both of very complex inheritance, presents a difficult problem. Most of the highly resistant varieties of wheat have some undesirable qualities from the standpoint of milling and baking. When many genes governing resistance to different physiologic forms of rust are brought together in a single strain of wheat it is often found that undesirable genes conditioning quality have been included in the genotype. If a type of resistance which is inherited in a simple manner and is effective against all physiologic forms could be used, the problem of combining rust resistance and quality would be much simplified. Such a type of resistance has been found and has recently been given much attention in wheat breeding work.

Certain wheat varieties, e.g., Hope, H-44, Pentad and Acme, although susceptible in the seedling stage to a number of physiologic forms, develop

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as they approach maturity a marked resistance to these same forms. Hayes and his associates (*9, 10*) first proved that certain wheat hybrids exhibited a high degree of resistance to rust in the field although they were susceptible in the seedling stage to a number of physiologic forms in the greenhouse. Goulden, Neatby and Welsh (*4*), in 1927, demonstrated that in the cross H-44 × Marquis the inheritance of the high resistance of H-44 could be explained on the basis of a difference in the parents of a single main pair of factors. In $F_3$ there was a 1:2:1 ratio of resistant, segregating and susceptible lines respectively on the basis of rust reaction in the field. This segregation was shown to be independent of the seedling reaction to physiologic form 36 and a group of forms including 21. The work was reported more fully in 1928 (*5*). The relatively simple inheritance of this type of mature plant resistance and the ease with which it may be used in plant breeding was made clear by Neatby and Goulden (*12*) in further studies involving a number of other crosses and by Clark and Ausemus (*2*) in 1928. Goulden reported a similar condition in crosses involving Pentad as the resistant parent (*3*).

Hart (*8*) in 1929 obtained evidence that certain wheat varieties are resistant to rust in the field because of the behavior of their stomata. She found that the stomata of the resistant varieties Hope, Webster, Acme, and Velvet Don opened later in the morning than those of the more susceptible varieties, Little Club, Baart, Quality, Reward and Marquis. Direct sunlight appeared to be the most important stimulus for the opening of the stomata. The following are some of Dr. Hart's conclusions:

"The critical period for stem rust infection is in the early morning immediately after sunrise and while the plants are heavy with dew. The fungus easily enters its host if the stomata are open during most of the critical period, but if they are closed during that time the fungus is excluded. There are great differences in the stomatal behavior of some wheat varieties during this critical period. . . . . .Some varieties of wheat are resistant to stem rust in the field because of the behavior of their stomata. Such varieties may be susceptible to stem rust in the seedling stages of their development."

Referring to the results of the cross H-44 and Marquis reported by Goulden et al and which they explain on the basis of a single factor pair difference, Hart points out the possibility that the factor in question may be one governing stomatal behavior. If such a relation between stomatal behavior and rust resistance existed it would be of utmost importance in wheat breeding.

## Materials and Methods

In the present experiments an attempt has been made to determine whether the suggested relation is to be found in certain wheat varieties. A useful critical method of testing the functional resistance hypothesis offers itself in the study of hybrids derived from a resistant and a susceptible parent. Suitable material from a cross, H-44 × Reward, was available at the Dominion Rust Research Laboratory, where the present study was conducted. A number of standard varieties were also studied. The rust reactions of some of these in the rust nursery of the Dominion Rust

Research Laboratory in 1930 are shown in figures 1 and 2. The samples shown were all grown within a few rods of each other in the same rust nursery so that the environmental conditions would not vary a great deal for different varieties. The epidemic was a severe one and involved over 30 physiologic forms of rust. H-44 and Hope were almost entirely free from rust in this test. However, it is common to find some rust pustules on these varieties on the leaf sheathe near the lowest node. The rest of the plant seems to be almost immune; the infection appears to be regional.

The stomata of different varieties were studied microscopically in the field to determine whether the rate of stomatal opening in the morning is correlated with the extent of rust infection as suggested by Hart's work. Stomata were studied on the leaves only for the following reasons:

1. The mature plant resistance of H-44, Hope and Pentad is exhibited by the leaves as well as the culms, and hybrids derived from these that have rust-resistant culms also have rust-resistant leaves.
2. The stomatal changes can be more distinctly detected on the leaves than on the culms and hence more accurate determinations can be made.
3. Leaves can be more easily manipulated on the microscope stage, so that more material can be examined in a given time.

The leaves were not removed from the plant. The stomata were observed under the low power of a standard microscope. For examination a leaf was drawn across the microscope stage, and, owing to the size and distinct outlines of the stomata, focussing was easily accomplished without the use of the fine adjustment. With practice, therefore, the operation can be done very quickly and a large number of leaves can be examined in a short time.

To express the degree of stomatal opening, the four classes used by Hart (*8*) were used, viz., wide open, half open, narrow slits, and closed. The first observations were made in the morning twenty minutes after sunrise and were repeated at the end of each succeeding twenty-minute period. A standard was also set for the proportion of stomata to be found with a certain opening in a sample of leaves from a given variety before a variety was to be recorded as having that degree of stomatal opening. Each variety was grown in a five-foot row. Six leaves of approximately the same age were examined in each plot. The stomata of a leaf were recorded as belonging to a certain class (e.g. narrow slits) when approximately one third of the stomata observed on the leaf had attained that opening. That class was assigned to the whole plot if two of the six leaves examined fell into that class. This is a purely arbitrary standard and it was introduced to make the determinations as objective as possible. It was felt that one-third of the stomata being open on one-third of the leaves should furnish ample opportunity for infecting hyphae of spores to enter the plants and become established. Even when conditions are most favorable for stomatal activity some stomata will be found to remain closed.

Figure 1. Field reactions of wheat varieties. Left to right; Khapli, Pentad, H-44, Hope, Webster.

Figure 2. Field reactions of wheat varieties. Left to right; Kota, Marquis, Velvet Don, Vernal Emmer, Marquillo.

The chief advantage of this method of studying stomata is that the conditions of the experiment are the actual field conditions. However, there are many varying factors that are not controlled. Light intensity, temperature, and humidity vary during the experiment. Soil heterogeneity might have an important effect on the experimental results. For a detailed study of stomatal activity, it would be desirable to devise more refined methods of study in which more factors are under control. It would seem, however, that if there exist under field conditions differences in stomatal behavior great enough to be the basis of functional resistance and susceptibility to rust, these differences should be easily detected in the field.

## Stomatal Behavior of Some Standard Varieties

The following seven wheat varieties were studied in the field: Webster R.L. 365,[3] Mindum R.L. 217, Pentad R.L. 203, H-44 R.L. 229, Ceres R.L. 127, Marquis R.L. 84, and Velvet Don R.L. 930.

The material was sown on May 22 and observations were made on seven mornings between July 5 and July 23, this period covering the time from the late boot stage to two weeks after the average date of heading. Care was taken to study leaves of approximately the same age. After heading the flag leaf only was used. The results are given in table 1, which shows the number of 20-minute periods required for each variety to attain each degree of stomatal opening. Light intensity seems to be the main factor governing stomatal opening. The amount of time after sunrise required before the stomata begin to open varies from day to day depending on whether the sun is clouded or not. Also the relative length of time that the stomata stay in the different stages of opening varies from day to day since the light intensity varies during each experiment due to the changing cloud conditions. Table 5 should be consulted in connection with tables 1, 2, 3 and 4. It will be seen in table 1 that the greatest uniformity of stomatal action was found in the first observations when the plants were 44 days old and that more variation appeared later. Varietal differences seem to develop. Velvet Don and Pentad, for example, appear to have a tendency to be later in stomatal opening than Marquis and Ceres.

In interpreting table 1 the question of the reliability of the data should first be considered. The leaves being examined were illuminated by direct light from above, the reflector on the microscope not being used. Under these conditions when a stoma opens slightly, the opening, due to the dark stomatal cavity below, appears as a dark slit in marked contrast to the light-colored guard cells. Distinction between the two classes "closed" and "narrow slits" can therefore be made with a reasonable degree of accuracy. Essentially, then, these classes represent respectively those stomata in which the openings are not wide enough to be detected under the conditions of the experiment and those stomata in which the openings are wide enough to be detected. Errors in the data for these two classes would be chiefly those due to random sampling of the leaves and of the parts of the leaves studied.

[3] Accession number, Dominion Rust Research Laboratory.

In the higher classes, however, the classification is more difficult and less reliable. The attempt to classify the stomata as half-open or open is made. The stomata pass gradually from the closed condition to the state of widest opening. When a leaf exhibits stomata at a great many stages of opening at the same time it is difficult to assign it to a simple class. Therefore, in attempting to draw conclusions as to differences in time of opening of stomata in different wheat varieties it would seem wise to use the data in the class "narrow slits". The same considerations would apply equally to tables 2, 3 and 4.

The averages for the class "narrow slits" in table 1 show the greatest values (i.e. the latest opening stomata) for Velvet Don and Pentad and the lowest values for Ceres and Marquis. Velvet Don and Pentad have mature plant resistance. This is evidence supporting the functional-resistance theory. Mindum, however, which is susceptible to rust, behaved in these experiments very similarly to Pentad which is highly resistant. These two Durum varieties were at comparable stages of growth as they differed by only one day in the time of heading. Stomatal behavior apparently cannot account for the different rust reactions on Mindum and Pentad. The durums appear in general to have later-opening stomata than the common wheats .

The so-called functional resistance is described as being due to the stomata remaining closed until after the dew has left the plants so that germ tubes of germinating rust spores are killed by dessication before they can enter the host. But since very heavy dews are common at Winnipeg during the period rust infects wheat, and since considerable dew is often found there on the wheat plants four hours after sunrise, it does not seem that the marked differences in reactions to rust in the wheat varieties used could be accounted for by the relatively small differences in stomatal behavior of the kind found in these experiments.

It should be noted here that some of the varieties in the foregoing test differ considerably in the length of time they require to develop to maturity. Hence though they were sown at the same time they were not all at the same stage of development when they were studied. If correction could in some way be made for this, the differences in stomatal behavior would be modified and might be greater or less.

### Stomatal Behavior in Resistant and Susceptible Wheat Hybrids

It is not safe to conclude from a study of the relatively small number of wheat varieties so far investigated that differences in stomatal behavior cause marked differences in rust reaction. The finding of rust resistance and late-opening stomata in the same variety suggests such an association, but it may be only apparent and needs more critical study before it is safe to generalize. One approach is the study of hybrid populations. If a resistant variety of wheat is believed to owe its resistance to late-opening stomata the hypothesis can be tested by crossing this variety with one that is quite susceptible to rust. If the hypothesis is true for the variety in question the resistant plants in the progeny should have later-opening stomata than the susceptible plants.

TABLE 1.—*The number of 20-minute periods after sunrise required for stomata of seven wheat varieties to open. (The symbols N, H and O represent the classes of stomatal openings, narrow slits, half-open and open, respectively. The numbers in the columns refer to the number of 20-minute periods required by the stomata to attain these openings).*

| | July 5 | | | July 12 | | | July 16 | | | July 19 | | | July 25 | | | July 28 | | | July 31 | | | Average | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | H | O | N | H | O | N | H | O | N | H | O | N | H | O | N | H | O | N | H | O | N | H | O |
| Webster | 6 | 7 | 7 | 4 | 7 | 8 | 5 | 6 | 9 | 5 | 7 | 9 | 6 | 7 | 8 | 6 | 6 | 7 | 7 | 8 | 9 | 5.6 | 6.9 | 8.1 |
| Mindum | 6 | 8 | 8 | 4 | 7 | 8 | 5 | 7 | 9 | 4 | 7 | 9 | 6 | 7 | 8 | 6 | 7 | 8 | 8 | 8 | 9 | 5.6 | 7.3 | 8.4 |
| Pentad | 6 | 8 | 8 | 5 | 7 | 8 | 6 | 7 | 9 | 6 | 8 | 10 | 6 | 7 | 8 | 6 | 7 | 8 | 7 | 8 | 9 | 6.0 | 7.4 | 8.6 |
| H-44 | 6 | 7 | 8 | 5 | 7 | 9 | 6 | 8 | 9 | 6 | 7 | 9 | 5 | 7 | 8 | 5 | 6 | 7 | 6 | 7 | 8 | 5.6 | 7.0 | 8.3 |
| Ceres | 6 | 7 | 7 | 4 | 6 | 7 | 3 | 6 | 7 | 3 | 6 | 7 | 5 | 6 | 7 | 5 | 6 | 6 | 6 | 6 | 7 | 4.6 | 6.1 | 6.9 |
| Marquis | 6 | 7 | 7 | 3 | 7 | 8 | 5 | 6 | 8 | 4 | 6 | 8 | 6 | 7 | 8 | 5 | 6 | 7 | 6 | 7 | 8 | 5.0 | 6.6 | 7.7 |
| Velvet Don | 6 | 7 | 8 | 6 | 7 | 9 | 6 | 8 | 9 | 5 | 7 | 10 | 6 | 7 | 9 | 6 | 7 | 8 | 7 | 8 | 9 | 6.0 | 7.3 | 8.9 |

TABLE 2.—*The number of 20 minute periods after sunrise required for stomata to open in Reward and H-44 and in four $F_4$ derivatives of a cross between these varieties. (For explanation, see table 1.)*

| Plot No. 1 | | June 20 | | | June 24 | | | June 26 | | | July 1 | | | July 9 | | | July 11 | | | July 24 | | | Average | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | H | O | N | H | O | N | H | O | N | H | O | N | H | O | N | H | O | N | H | O | N | H | O |
| 1 | Reward | 4 | 5 | 7 | 5 | 6 | 9 | 4 | 6 | 7 | 6 | 8 | 10 | 4 | 5 | 7 | 5 | 6 | 7 | 7 | 8 | 9 | 5.0 | 6.3 | 8.0 |
| 2 | H-44 | 4 | 5 | 7 | 5 | 6 | 8 | 5 | 6 | 7 | 6 | 8 | 10 | 5 | 7 | 8 | 5 | 6 | 7 | 7 | 7 | 8 | 5.3 | 6.4 | 7.9 |
| 3 | Susceptible | 4 | 5 | 7 | 5 | 6 | 9 | 4 | 5 | 7 | 6 | 8 | 10 | 5 | 6 | 7 | 5 | 6 | 7 | 5 | 7 | 8 | 4.9 | 6.1 | 7.9 |
| 4 | Resistant | 4 | 5 | 7 | 5 | 6 | 8 | 5 | 6 | 7 | 5 | 7 | 10 | 5 | 6 | 7 | 5 | 5 | 6 | 6 | 6 | 7 | 5.0 | 5.9 | 7.4 |
| 5 | Susceptible | 4 | 5 | 7 | 5 | 6 | 8 | 4 | 6 | 7 | 5 | 8 | 11 | 4 | 7 | 8 | 5 | 5 | 6 | 5 | 6 | 7 | 4.6 | 6.1 | 7.7 |
| 6 | Resistant | 4 | 5 | 7 | 5 | 6 | 8 | 4 | 5 | 7 | 6 | 8 | 10 | 4 | 6 | 7 | 5 | 6 | 6 | 5 | 7 | 8 | 4.7 | 6.1 | 7.6 |

TABLE 3.—*The number of 20-minute periods after sunrise required for stomata to open in six $F_4$ derivatives of a cross between H-44 and Reward. (For explanation see table 1.)*

| Plot No. | | June 21 | | | June 25 | | | June 27 | | | July 2 | | | July 10 | | | Average | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | H | O | N | H | O | N | H | O | N | H | O | N | H | O | N | H | O |
| 7 | Susceptible | 2 | 4 | 6 | 5 | 6 | 10 | 6 | 7 | 8 | 7 | 8 | 9 | 6 | 8 | 9 | 5.2 | 6.6 | 8.4 |
| 8 | Resistant | 2 | 5 | 6 | 6 | 7 | 11 | 7 | 8 | 10 | 7 | 8 | 10 | 7 | 7 | 9 | 5.8 | 7.0 | 9.2 |
| 9 | " | 2 | 5 | 6 | 6 | 7 | 11 | 6 | 7 | 10 | 7 | 9 | 9 | 6 | 8 | 9 | 5.4 | 7.2 | 9.0 |
| 10 | " | 2 | 5 | 6 | 6 | 7 | 11 | 6 | 8 | 10 | 6 | 8 | 9 | 5 | 8 | 8 | 5.0 | 7.2 | 8.8 |
| 11 | Susceptible | 2 | 4 | 6 | 5 | 7 | 10 | 6 | 8 | 9 | 6 | 8 | 9 | 5 | 7 | 8 | 4.8 | 6.8 | 8.4 |
| 12 | " | 2 | 5 | 6 | 5 | 6 | 10 | 6 | 7 | 8 | 6 | 7 | 9 | 5 | 7 | 9 | 4.8 | 6.4 | 8.4 |

In the present experiment hybrids from the cross H-44 × Reward were studied, the former being the resistant parent and the latter susceptible. $F_3$ lines had been grown in 1929 in the rust nursery at Winnipeg where a severe epidemic of rust had been induced artificially. Lines were selected that were uniformly susceptible, the reaction being somewhat similar to that of Marquis in figure 2, and also lines with a high resistance of the type of H-44 in figure 1. These lines were sown on April 29, 1930, in five-foot rows, the resistant and susceptible lines being arranged at random so that when the microscopic work was done on them later their identity, record of which had been kept in the planting plan, was unknown to the writer. The stomata were studied microscopically as described above for the wheat varieties. Two separate experiments were carried, one involving the two parent varieties and four hybrid lines, the other including six hybrid lines. The results are given in tables 2 and 3. As before, chief weight should be given to the data in the column marked N (narrow slits). There appear to be no differences in stomatal behavior that are distinctly associated with differences in rust reaction. Since the resistant lines were almost immune to stem rust while the others were quite susceptible, differences in stomatal behavior that would account for these conditions should be distinct and consistent. No such differences are evident in tables 2 and 3. The data indicate that the differences in rust reaction of H-44 and Reward cannot be explained on the basis of stomatal behavior.

In both tables 2 and 3 the values of the averages decrease in general from top to bottom. This may be used as an indication of the efficiency of the method of obtaining the data. The plots were always examined in the same order, from 1 to 6 and from 7 to 12. It required about 6 minutes to examine a series of 6 plots. The last plot examined is likely to have its stomata more widely open than the first one since it is exposed to the sunlight 6 minutes longer before it is examined. This results in smaller numbers in the tables for the plots near the end of the series. The general decrease of the averages from top to bottom in the tables indicates that the methods used may detect stomatal differences due to 6 minutes extra exposure to light.

The difficulty due to different stages of development of the different varieties in the previous experiment was not serious in the study of these hybrids as indicated by the dates of heading. Reward headed on June 28, H-44 on June 30, and the progeny all came within this range.

Table 4 shows the results obtained from six single $F_2$ plants from the cross Renfrew × H-44. Renfrew is a susceptible variety. The rust resisting capabilities of these plants were not known until the rust developed on them. The plants were not always examined in the same order as were the plots in the previous experiments. Here again there is no positive evidence that the resistance is due to stomatal behavior.

Table 5 shows the meteorological conditions during the experiments. A thermograph was kept in the field to obtain temperature and humidity data.

TABLE 4.—*The number of 20-minute periods after sunrise required for stomata to open in six $F_2$ plants from a cross between Renfrew and H-44.*
*(For explanation see table 1.)*

| Plot No. | | July 22 | | | July 26 | | | July 30 | | | August 1 | | | Average | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | H | O | N | H | O | N | H | O | N | H | O | N | H | O |
| 1 | Susceptible | 4 | 5 | 6 | 3 | 6 | 6 | 4 | 6 | 7 | 4 | 5 | 7 | 3.8 | 5.5 | 6.5 |
| 2 | " | 3 | 5 | 6 | 3 | 6 | 7 | 4 | 6 | 8 | 3 | 4 | 5 | 3.3 | 5.3 | 6.5 |
| 3 | Moderately susc. | 3 | 5 | 7 | 3 | 6 | 7 | 5 | 6 | 8 | 4 | 5 | 7 | 3.8 | 5.5 | 7.3 |
| 4 | Resistant | 4 | 5 | 7 | 3 | 4 | 5 | 4 | 5 | 7 | 4 | 5 | 7 | 3.8 | 4.8 | 6.5 |
| 5 | " | 4 | 5 | 7 | 3 | 4 | 6 | 5 | 6 | 8 | 4 | 5 | 7 | 4.0 | 5.0 | 7.0 |
| 6 | " | 3 | 4 | 6 | 4 | 6 | 7 | 4 | 5 | 8 | 5 | 5 | 6 | 4.0 | 5.0 | 6.8 |

TABLE 5.—*Meteorological conditions during stomatal observations.*

| Date | Sunrise | Relative Humidity | | Temperature | | Dew | Light Conditions |
|---|---|---|---|---|---|---|---|
| | | At Sunrise | Average* during experiment | At sunrise | Average* during experiment | | |
| June 20 | 4.18 | 82 | 65 | 56 | 64 | heavy | Almost clear sky. |
| " 21 | 4.18 | 87 | 72 | 52 | 61 | " | Clear sky. |
| " 24 | 4.19 | 84 | 73 | 56 | 62 | light | Light clouds, sun bright at 5.45. |
| " 25 | 4.19 | 87 | 75 | 52 | 61 | heavy | Clouds over sun heavy & light at intervals then bright at 7.35. |
| " 26 | 4.20 | 85 | 76 | 52 | 60 | " | Sun bright & clouded at intervals. |
| " 27 | 4.20 | 80 | 64 | 48 | 59 | very light | Light clouds. |
| July 1 | 4.22 | 82 | 77 | 51 | 59 | none | Clouds heavy, then light, sun bright at 7.30. |
| " 2 | 4.23 | 83 | 77 | 57 | 62 | heavy | Heavy clouds. |
| " 5 | 4.25 | 79 | 72 | 56 | 61 | " | Clouds heavy, light at 6.25. |
| " 9 | 4.28 | 87 | 86 | 64 | 66 | " | Clear sky. |
| " 10 | 4.29 | 85 | 85 | 70 | 72 | very light | Clouds heavy until 6.45, then light. |
| " 11 | 4.30 | 87 | 86 | 65 | 66 | light | Clouds heavy until 5.50, then light. |
| " 12 | 4.32 | 85 | 84 | 64 | 66 | rain | Clouds heavy, gradually lighter; sun bright at 6.30. |
| " 14 | 4.33 | 89 | 83 | 46 | 50 | none | Clear sky. |
| " 16 | 4.35 | 86 | 80 | 55 | 62 | light | Almost clear sky. |
| " 19 | 4.40 | 86 | 80 | 50 | 59 | heavy | Light clouds |
| " 22 | 4.42 | 86 | 85 | 52 | 56 | " | Almost clear sky. |
| " 24 | 4.45 | 88 | 86 | 53 | 60 | " | Almost clear sky. |
| " 25 | 4.46 | 85 | 78 | 67 | 70 | none | Clouds heavy until 6.00, then sun bright. |
| " 26 | 4.49 | 85 | 84 | 65 | 68 | heavy | Clear sky. |
| " 28 | 4.50 | 87 | 78 | 53 | 57 | light | Almost clear sky. |
| " 30 | 4.53 | No thermograph data obtained | | | | light | Clear sky. |
| " 31 | 4.54 | 91 | 73 | 46 | 58 | " | Light clouds. |
| Aug. 1 | 4.56 | 92 | 81 | 62 | 67 | none | Clear sky. |

* The average here given is the average of the highest and lowest reading during the experiment.

## RUST INFECTION THROUGH CLOSED STOMATA

In the study of rust resistance in relation to stomatal behavior it is of importance to know whether the parasite can enter the plant through closed stomata.

Hart (*8*) inoculated wheat seedlings with rust and kept them in moist chambers in the dark for 6, 12 and 24 hours in different experiments. Hart found that no stomata opened in the dark moist chambers and no infection of the plants took place except through the hydathodes. In another experiment inoculated plants were kept in moist chambers 24 hours, some of them in the dark for the entire period and others being exposed to the light for the latter half of the period. A few pustules developed on the plants exposed to the light and none on those kept in the dark. On the basis of these results and histological studies Hart concludes that the rust fungus generally does not enter the host plant if the stomata are closed. The results lend support to the theory of functional resistance. Under field conditions, however, plants do not have both sunlight and dew for 12 hours as in the above experiments. These experiments indicate that germ tubes of rust enter the host more readily through open than through closed stomata. But that the differences in the rate of stomatal opening of different wheat varieties are sufficient to cause appreciable differences in rust infection under field conditions has not yet been positively demonstrated.

According to the theory advanced by Hart, functional resistance in wheat is due to the relatively slow opening of the stomata in response to the stimulus of light. It follows then that if plants of different varieties show marked differences in rust reaction as a result of infection in the dark, through closed stomata, these differences cannot be due to functional resistance. In the present experiment the rust reactions on H-44 and Marquis resulting from infection in the absence of light were studied[4]. Use was made of the fact demonstrated by Brown[5] that rust readily infects wheat through closed stomata if the inoculation period allowed is somewhat longer than in the experiments of Hart.

Seedlings of Marquis and H-44 in pots were placed in a photographic dark room. After five hours their leaves were examined microscopically and as near as could be determined no stomata were open. They were then inoculated with urediniospores of *Puccinia graminis tritici*, form 9, to which both varieties are susceptible in the seedling stage, Marquis showing type 4– reaction and H-44 a 3 ± type. Three methods of inoculation were used for both varieties. In the first group the leaves were drawn through the moistened fingers and the inoculum was applied with a flat inoculating needle; in the second group the inoculum was applied in the dry leaves with the needle; and in the third group the leaves were atomized and the inoculum was dusted on them from heavily rusted plants. All the plants were then atomized and placed in moist chambers lined with blotting paper where they were left for 48 hours. Check plants were examined from time to time and no stomata were found open. After being removed the plants were kept in the dark for 3 hours to dry and then placed on the greenhouse bench in the light. Eighteen days after inoculation all plants showed heavy infection. Results were similar for the different methods of inoculation. Figure 3 shows typical leaves 18 days after inoculation. Another group of H-44 and Marquis seedlings was inoculated by dusting uredinio-

4 The writer wishes to thank A. M. Brown for his kind assistance in the inoculation work.
5 Unpublished data of A. M. Brown.

spores on the plants and allowing a 48-hour inoculation period in the dark with like results. This illustration is given for the purpose of comparison with mature plant reactions, a discussion of which follows.

In one experiment month-old plants of H-44 and Marquis were used. One day at 7.30 a.m. 25 plants of each variety in pots were taken from the greenhouse and placed in the photographic dark room. Microscopic examinations of the leaves were made at the time and no stomata were found to be open. After 2½ hours the stomata were again examined and none were found open. The leaves were gently drawn through the moistened fingers and were then inoculated with *Puccinia graminis tritici*, form 9, as in the experiments with the seedlings. The urediniospores were applied with a flat inoculation needle. The plants were atomized and placed in moist chambers lined with blotting paper to increase the humidity. They were left there 52 hours in the dark.

During the incubation period the temperature of the dark room kept within the range of 62° to 64°F. The plants were removed from the moist chamber and left in the dark overnight for a period of 16 hours. In the morning the leaves were dry and the plants were returned to the greenhouse bench. Care was taken in watering the plants that no moisture reached the leaves where it might cause spores to germinate. Seven days after inoculation flecks were seen in the leaves of Marquis, showing that infection had taken place. This was 4 days and 4 hours after the plants were brought into the light, so it is evident that the infection took place in the dark. Eight days after inoculation very small pustules had broken out on Marquis leaves, and a small number of flecks were found on H-44. Nine days after inoculation the pustules on Marquis were quite marked and

Figure 3

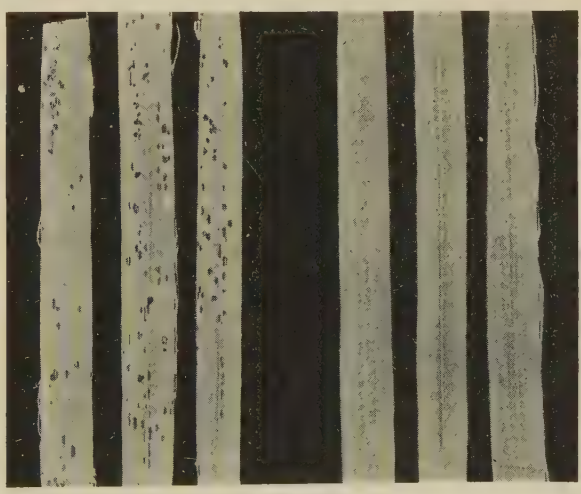

Figure 4

Figure 3. Rust reactions on seedlings inoculated with form 9 and infected through closed stomata in the dark. Left, Marquis; right, H-44.

Figure 4. Rust reactions on wheat varieties inoculated when one month old with form 9 and infected through closed stomata in the dark. Left, Marquis; right, H-44.

on the tenth day a few small pustules were found on H-44. On the fifteenth day the rust pustules on the Marquis leaves were type 3+ while on H-44 they were type 1—. Figure 4 shows typical reactions on leaves of the two varieties at this time. By the twentieth day after inoculation the contrast was still greater. The rust on Marquis plants had developed much and showed type 4 pustules while the reaction on H-44 had changed little and showed flecks to type 1+ pustules. All the 25 Marquis plants and 17 of the 25 H-44 plants had pustules and flecks. The remaining 8 plants of H-44 had flecks but no pustules. It would appear that H-44 develops, as it approaches maturity, a physiologic resistance to form 9. Since H-44 becomes resistant to all forms of stem rust in the field it is not improbable that H-44 develops a physiologic resistance that is effective against all these forms. This has been indicated in the work of Goulden, Newton and Brown (*6*). They determined the rust reactions of fourteen wheat varieties in the after-heading stage to 16 physiologic forms of rust. In the varieties H-44, Hope, Pentad, Acme and Black Persian all physiologic forms that produced large pustules on seedlings, developed distinctly smaller pustules on the mature plants. In other varieties such as Garnet, Marquis and Quality, physiologic forms that produced large pustules on seedlings gave similar reactions on the mature plant. An earlier study by Harrington and Smith (*7*) showed that a strain of Iumillo that was susceptible in the seedling stage to certain physiologic forms became more resistant in the after-heading stage.

The experiment was repeated with 18 plants of Marquis and 23 of H-44 in the boot stage, one week older than those used before. The procedure was the same except that the plants were placed in the dark room at 9.00 p.m. and left there overnight before they were inoculated. After being 52 hours in the dark moist chambers they were left in the dark room overnight to dry. Twenty Marquis seedlings in pots were placed in the dark room at this time. In the morning these seedlings were moistened and inoculated with form 9 as the older plants had been. All the plants were then placed on the greenhouse bench in the light. The purpose of using the seedlings was to determine if any infection takes place in the greenhouse after the plants are brought to the light. Seven days after inoculation a number of flecks were seen on the older Marquis plants and some indications of indistinct flecks on H-44. The check seedlings showed no flecks. Next day a few small pustules were found on Marquis and many flecks. There appeared to be flecks on H-44 but they were not very distinct. On the ninth day the number of pustules on Marquis had increased and the flecks were easily seen on H-44. On the twelfth day a number of small pustules were found on H-44. No sign of infection was yet seen on the check seedlings but next day a small pustule appeared at the extreme tip of one of the leaves. Drops of moisture often collect at the leaf tips and if inoculum is present infection is likely to take place. The following day another seedling leaf tip carried a pustule. On the fifteenth day after inoculation, the reactions on Marquis and H-44 were practically the same as those obtained in the same period in the previous experiment and shown in figure 4 except that the development on H-44 was somewhat slower. The reaction on Marquis was 3± and on H-44 it ranged

from flecks to 1–. No sign of infection could be found on the check seedlings apart from the two pustules on the leaf tips already mentioned.

To test whether the stomata of wheat plants open under the conditions of the above experiments, six plants of each of Marquis and H-44, 1½ months old and growing in pots, were atomized and kept in moist chambers in the dark for 52 hours. The leaves were examined under the low power of a microscope at two hour intervals between 6.00 a.m. and 6 p.m., and during the night hours they were examined at four-hour intervals. An electric light was used for examinations. After each examination the plants were atomized and replaced in the moist chambers. As far as could be determined, no stomata opened during the 52 hour period. Doubtless there are under these conditions stomatal movements associated with transpiration but too slight to be detected by the methods used.

The results of these experiments show that there is a marked difference in the rust reaction of H-44 and Marquis to form 9 which is independent of the influence of light and therefore independent of the rate of stomatal opening in response to the stimulus of light. The fact that the incubation period for the rust in these experiments was longer than would occur ordinarily under field conditions does not detract from this conclusion. The difference in the rust reaction of the two varieties found here can therefore not be due to "functional resistance" as described by Hart (*8*).

The nature of the resistance of H-44 is indicated by the rust reactions shown in figure 4. The presence of hypersensitive flecks shows that germ tubes have entered the leaves and killed some of the host cells and have then had their development stopped. This and the small uredinia surrounded by necrotic areas indicate a physiologic resistance to form 9. In the seedling stage H-44 is moderately susceptible to this form.

### Effect of Lengthening the Dew Period

Hart (*8*) states that the critical period for stem rust infection is in the morning immediately after sunrise and while the plants are heavy with dew, and that the fungus easily enters its host if the stomata are open during most of the critical period, but is excluded if the stomata are closed during that time. Functional resistance is described as being due to the latter condition. It must follow that if earlier stomatal opening could be induced or if the dew period could be prolonged, the degree of functional resistance of the host to the fungus could be lowered.

The writer sprayed plants with soft water, effecting what practically amounted to a prolonging of the dew period, in order to secure more evidence as to the nature of stem rust resistance in wheats derived from the crosses H-44 × Marquis and Pentad × Marquis. The material used consisted of an $F_6$ strain of H-44 × Marquis having the characteristic high resistance of H-44 and an $F_5$ strain of Pentad × Marquis having the high resistance of Pentad. Both had just completed flowering. Eight small plots of each strain were used, alternate plots being sprayed so that the unsprayed could be used as checks. Other plots between these were used to prevent spray from reaching the check plots. The water used was kept in an open container in the field so that its temperature would approximate that of the

dew. It was applied by means of a small hand-pump which delivered a very fine spray so that it adhered to the plants as a film and did not run.

The spraying was begun in the morning shortly after sunrise while the plants were still wet with dew, and was continued until 9.00 a.m. so that the plants were covered with a film of moisture during the whole period. This was done on four successive mornings. The first morning there was a heavy dew. The sun rose at 4.49 and the sky was cloudless. Leaves were examined at 7.15 a.m. and many stomata were found half open. At 8.00 a.m. there was still considerable dew on the unsprayed plots. At 9.00 a.m. some dew could still be found on the lower parts of the plants and at 9.30 traces of dew were still found. On the second morning, the plants were wet with rain and the sun was bright. There was a light dew on the third morning and the sun was slightly clouded. On the fourth morning the dew was light and the sun was bright.

The spraying test was conducted in a field where an artificial epidemic of rust involving over 30 different physiologic forms had been induced. The inoculum was very abundant and weather conditions so favorable to rust development that plants of Marquis and most other susceptible varieties in the vicinity of this test carried over 75 per cent rust. The natural spore shower at Winnipeg during these four days (July 26 to July 29) was quite heavy as shown by glass slides coated with vaseline exposed to the air for 24 hours. The number of spores of stem rust per square inch on the slides was estimated to be as follows: July 26, 2,750; July 27, 1,020; July 28, 2,100; and July 29, 4,200.

One month after the spraying work the wheat was ripe and rust readings were made. In both strains, the plants showed from 5 to 10 per cent rust, and while there may possibly have been some minute difference in the degree of infection in sprayed and unsprayed plots, no differences could be detected by the ordinary standards of reading rust in the field. If the resistance of H-44 and Pentad is of a functional nature and dependent on stomata remaining closed during the dew period, a distinct difference in rust development on sprayed and unsprayed plots would be expected.

## Discussion

The theory of functional resistance as advanced by Hart (*8*) is based chiefly on differences she found in the rate of opening of the stomata of different wheat varieties in response to sunlight. In four varieties that are resistant under field conditions, Hope, Webster, Acme and Velvet Don, the stomata were found to open more slowly than those of the susceptible varieties Little Club, Early Baart, Quality and Reward. Kota and Kubanka which are moderately resistant were reported as having an intermediate type of stomatal behavior.

Hope and H-44 are sister strains, both having been produced by McFadden (*11*) from the cross Yaroslav Emmer × Marquis. These two strains, Hope and H-44 are very similar and both derive their resistance from the same parent, Yaroslav Emmer. There can be little doubt, therefore, that the fundamental nature of the rust resistance of each is the same, and on this basis H-44 and Hope should belong to the same group. In the

present study, however, no significant difference was found between H-44 and Reward on the basis of rate of stomatal opening, nor between resistant and susceptible hybrid lines derived from the cross H-44 × Reward. This is not in accord with expectations based on the results of Hart.

There are a number of other considerations that would be difficult to bring into agreement with the theory of functional resistance. Webster and Hope that have been placed in the same class on the basis of stomatal behavior have very different types of rust reaction in the field (figure 1). Hope usually appears free from infection except for occasional "regional susceptibility" while Webster often shows a high percentage of infections but the pustules are small and confined. The type of resistance in Webster that limits the size rather than the number of the pustules would be difficult to explain on the basis of stomatal behavior. The data given by Goulden, Newton and Brown (*6*) compared seedling and mature plant reactions of 14 wheat varieties to 16 physiologic forms. It appears that in H-44, Hope, Acme, Pentad and Black Persian, those physiologic forms that produce large pustules on seedlings show smaller pustules and a lower percentage of infection on mature plants, while in varieties liike Garnet, Marquis and Quality there is a close agreement between seedling and mature plant reactions. The progressive decrease in pustule size as plants approach maturity found in the first group of varieties indicates a resistance that is not dependent on stomatal behavior. The decrease in percentage of infection might be attributed to stomatal behavior, but the fact that the plants were kept moist in moist chambers for two days after inoculation makes this seem improbable. It would seem more probable that the agency causing a decrease in pustule size was also responsible for the appearance of fewer pustules. Figure 3 in the study by Hart (*8*) shows graphically the behavior of stomata of six wheat varieties under field conditions during the early morning hours of July 3, 1928. Kota and Hope are shown as having their stomata narrowly open at the same time, Kota as being one period (20 minutes) behind Hope in having the stomata half open, and both varieties as having their stomata wide open at the same time. Hart, on the basis of data taken throughout the season, places Hope in the class of varieties having later-opening stomata and high rust resistance, and Kota in a class intermediate between classes having early and late-opening stomata, and with moderate rust resistance. The actual difference found in stomatal behavior shown in the published data for the one day, however, seems rather small to be of any significance. While it seems evident that in a number of resistant varieties stomatal behavior is not the cause of the main resistance it should be borne in mind that, in these varieties, it still may play a part, though a minor one.

The results of the present experiment indicate strongly that the main resistance of the two varieties H-44 and Pentad is not due to stomatal behavior.

## Summary

1. The purpose of this study was to determine whether there is a relation between stomatal behavior and resistance to stem rust in H-44 and certain other wheat varieties.

2. The movements of stomata were studied microscopically under field conditions during the early morning hours. The tests included certain susceptible and resistant standard varieties as well as susceptible and resistant hybrids from the crosses H-44 × Reward and H-44 × Renfrew.
3. In the standard varieties some differences in stomatal behavior were found but these did not seem great enough to account for differences in rust reaction and some of them were not in accord with the functional resistance theory. The stomata of the two durums, Pentad and Mindum, for instance, behaved alike although Pentad is resistant and Mindum susceptible.
4. In the hybrids studied, only slight differences in stomatal behavior between different strains were found, and these did not appear to be correlated with the rust reaction.
5. Marquis and H-44 plants, inoculated with *Puccinia graminis tritici*, form 9, and incubated in the dark showed marked differences in rust reaction. Since these differences were independent of the stimulus of light, they were not due to functional resistance. The type of reaction on H-44 suggests that this variety possesses at the heading stage a physiologic resistance to form 9 not possessed in the seedling stage.
6. Spraying resistant hybrid plants of H-44×Marquis and Pentad×Marquis with soft water in the morning to prolong the dew period did not increase the per cent of rust infection as might be expected if their resistance were due to late stomatal opening.
7. It is concluded that the main resistance of H-44, Hope and Pentad is not due to stomatal behavior.
8. A discussion is given of some facts that are difficult to reconcile with the theory of functional resistance.

## Acknowledgments

The writer wishes to express his thanks to Dr. H. K. Hayes, Chief of the Division of Agronomy and Plant Genetics, University of Minnesota, for helpful criticism in the preparation of this paper, and to Dr. C. H. Goulden and Dr. K. W. Neatby of the Dominion Rust Research Laboratory, Winnipeg, for suggesting the project and giving helpful advice in its execution.

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## CURRENT PUBLICATIONS

15. Trannsporting and Handling Milk in Tanks. Ralph P. Hotis. United States Department of Agriculture Technical Bulletin No. 243. Available at the price of 10 cents from the Superintendent of Documents, Washington.

The advantages of tank-truck and tank-car hauling over the hauling of milk in cans are as follows: Better temperature control of product, greater sanitation, smaller investment in cans, less loss of milk, less labour at country plants, the handling of more milk in the same area by the city plant, saving in washing powder and in man-hours required for washing, the affording of an advertising medium for firm names and slogans, and reduction in floor space required in country plants.

Tank-truck hauling has proved uneconomical under the following conditions: Shippers situated a short distance from the plant, small supply of milk from one community, poor roads, and exceedingly long routes where climatic conditions are severe.

Under favourable conditions tank-truck transportation has advantages over tank-car transportation; at present, however, the tank-car is the only practical means of extending the milk shed beyond the 330 to 500 mile zone and at the same time maintaining the quality of the milk without extra expense en route.

16. Manures and Fertilizers. F. T. Shutt and L. E. Wright. Dominion of Canada Department of Agriculture Bulletin No. 145—New Series. Available from Publications Branch, Ottawa.

This bulletin replaces 'Fertilizers for Field Crops' and 'Soil Fertility', two bulletins dealing with the nature and use of fertilizers and manures, which for some time past have been out of print. Much of the material in these publications has been incorporated into the present bulletin, but the whole has been rewritten and a considerable amount of new matter, based on the results of recent experiments with manures and fertilizers conducted by the Division of Chemistry, included. In the preparation of this bulletin the close relationship of the use of manures and fertilizers to the maintenance and increase of soil fertility has been kept in mind. It treats concisely of the following important phases of the subject:

Farm manures; their nature, care and application.
Green manures; their value and function.
Commercial fertilizers; their plant food content and economic use.
Soil amendments.

# SOAKED BEET PULP VERSUS MALT SPROUT–BARLEY SCREENING–MOLASSES MIXTURE AS A SUCCULENT FEED FOR COWS IN MILK

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[Received for publication March 25, 1931]

The difficulty of supplying an economical succulent feed for dairy cattle in Eastern Canada is one of some importance with many dairymen, particularly those who have neither silage nor fresh roots.

The best known substitute for either of these succulent feeds is beet pulp, but in addition to being difficult to obtain, the price is usually such that it must compete in the ration with concentrate feeds.

There is another product, much less well-known, but which for some years has been used for this purpose to a limited extent by certain dairy cattle feeders, namely, malt sprouts.

Used alone, this product is rather unpalatable to dairy cattle, but mixed in equal parts with beet pulp, with or without the addition of molasses, this product proves very satisfactory from the standpoint of nutrition. The cost of this product is relatively low, certainly as compared to beet pulp, and the combination, therefore, seems more economical and satisfactory than either alone.

In the manufacture of malt there are in addition to malt sprouts a number of other by-products including barley screenings, skimmings, weed seeds and chaff.

By chemical analysis it seems likely that these other by-products in mill-run proportions should contain considerable feeding value and the possibility of combining them with the malt sprouts has been considered by the Canada Malting Company.

At the request of this concern, a feeding trial was organized in April 1930. Ten pairs of dairy cows were chosen, one member of each pair to receive in addition to her meal and hay allowance, a succulent feed consisting of beet pulp soaked in four times its weight of water. The other member of each pair received in place of the beet pulp an equal allowance, (on a dry weight basis) of the malt sprout-barley screening combination, plus 15 per cent of molasses. This mixture was also soaked in four times its weight in water. Due to sickness (not connected with feed) of one cow, it was necessary to remove one pair of cows from the trial.

Feed was so adjusted that equal quantities (dry weight basis) of the succulent feed and the hay were fed to pair mates. Meal allowances were based on daily milk production.

These cattle went on feed on April 11th, and were fed for a period of thirty days.

Table 1 gives the complete data for this feeding period and table 2 a summary of the essential features.

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TABLE 1.—*Beet Pulp vs. Malt Sprout-Barley Screening-Molasses Mixture as a succulent feed for cows in milk.*

| LOT I. BEET PULP | | | | | | | | LOT II. MALT SPROUT—BARLEY SCREENING—MOLASSES MIXTURE | | | | | | | | Statistical Analysis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feed Eaten 30 Days | | | | | Production 30 Days | | | | Feed Eaten 30 Days | | | | Production 30 Days | | | | |
| Cow No. | Meal | Succulent Mix | Hay | Total Dry Matter | Lbs. Milk | % Fat | F.C.M. | F.C.M. per 100 lbs. D.M. | Cow No. | Meal | Succulent Mix | Hay | Total Dry Matter | Lbs. Milk | % Fat | F.C.M. | F.C.M. per 100 lbs. D.M. | Difference in F.C.M. per 100lbs. D.M. |
| 1 | 210 | 248 | 248 | 706 | 412.0 | 4.1 | 418.2 | 59.23 | 1a | 195 | 279 | 248 | 722 | 370.9 | 4.0 | 370.9 | 51.37 | — 7.86 |
| 2 | 423 | 310 | 310 | 1043 | 1367.2 | 4.0 | 1367.2 | 131.08 | 2a | 435 | 348 | 310 | 1093 | 1637.8 | 4.7 | 1809.8 | 165.58 | +34.50 |
| 3 | 400 | 310 | 310 | 1020 | 1340.9 | 3.5 | 1240.3 | 121.59 | 3a | 395 | 348 | 310 | 1053 | 1209.4 | 3.2 | 1064.3 | 101.07 | —20.52 |
| 4 | 364 | 310 | 270 | 944 | 1058.6 | 3.8 | 1026.8 | 108.77 | 4a | 364 | 348 | 270 | 982 | 1092.6 | 4.6 | 1190.9 | 121.27 | +12.50 |
| 5 | 380 | 310 | 310 | 1000 | 1184.5 | 3.7 | 1131.2 | 113.12 | 5a | 350 | 348 | 310 | 1008 | 1167.3 | 3.7 | 1114.8 | 110.59 | — 2.53 |
| 6 | 375 | 310 | 310 | 995 | 922.0 | 4.6 | 1004.9 | 100.99 | 6a | 396 | 348 | 310 | 1054 | 1194.6 | 4.4 | 1254.3 | 119.0 | +18.01 |
| 7 | 400 | 310 | 310 | 1020 | 1219.3 | 3.7 | 1164.4 | 114.16 | 7a | 386 | 348 | 310 | 1044 | 1480.8 | 4.2 | 1525.2 | 146.09 | +31.93 |
| 8 | 275 | 248 | 248 | 771 | 633.3 | 5.4 | 766.3 | 99.39 | 8a | 270 | 279 | 248 | 797 | 501.1 | 4.9 | 568.7 | 71.35 | —28.04 |
| 9 | 222 | 248 | 248 | 718 | 958.9 | 4.9 | 1088.4 | 151.58 | 9a | 210 | 279 | 248 | 737 | 731.3 | 4.4 | 767.9 | 104.19 | —47.39 |
| 10 | Removed | | | | | | | | | | | | | | | | | $Md=\frac{-9.4}{9}$ |
| Total | 3049 | 2604 | 2604 | 8217 | 9096.7 | | 9207.7 | | | 3001 | 2925 | 2564 | 8490 | 9385.8 | | 8666.8 | | = −1.04 |
| Average | 338.8 | 289.2 | 289.2 | 913.0 | 1010.7 | | 1023.1 | 112.1 | | 333.3 | 325 | 294.9 | 943.3 | 1042.9 | | 961.9 | 102.1 | |

Mean difference between pairs in Fat Corrected Milk produced per 100 lbs. Dry Matter eaten in favor of Lot I (Beet Pulp).... 1.04 lbs.
Standard deviation of differences in production between pair mates ($\sigma$).... 26.3 "
Necessary Z value for odds of 30 to 1 (9 pairs).... .762
Necessary difference in production per 100 lbs. Dry Matter Eaten.... 20. lbs.
Net difference creditable to difference in rations.... None

TABLE 2.—SUMMARY OF DATA.

*Beet Pulp vs. Malt Sprout–Barley Screening–Molasses Mixture as a succulent feed for cows in milk.*

| | LOT I Beet Pulp | LOT II Malt Sprout-Barley Screening-Molasses Mixture |
|---|---|---|
| No. Cows | 9 | 9 |
| Days Fed | 30 days | 30 days |
| Av. daily Feed | | |
| Meal | 11.3 lbs. | 11.1 lbs. |
| Beet Pulp | 9.6 " | |
| Malt Sprout Mixture | | 10.8 " |
| Hay | 9.6 " | 9.8 " |
| Av. Total Dry Matter per day | 30.4 " | 31.4 " |
| Av. Daily production | | |
| Milk | 33.7 " | 34.7 " |
| Fat Corrected Milk | 34.1 " | 32.6 " |
| Av. Fat Corrected Milk per 100 lbs. Dry Matter | 112.1 " | 102.1 " |

| | |
|---|---|
| Mean difference between pair mates in favor of Lot I (Beet Pulp) in F.C.M. per 100 lbs. Dry Matter Eaten | 1.04 lbs. |
| Necessary difference | 20. " |
| Net difference due to feed | None |

## DISCUSSION

It will be noted from the data of tables 1 and 2 that there was no measurable difference observed between the milk production per unit of dry matter consumed in the one ration as compared with the other.

With the variability prevailing, a difference of at least 20 pounds of fat corrected milk for each 100 pounds of dry matter consumed would have to be allowed for uncontrolled variability. This allowance may seem high, but it is due largely to the short feeding period.

Actually, there was observed but a difference of 1.1 pound of fat corrected milk per 100 pounds of dry matter eaten, and this in favour of the beet pulp fed lot. This difference is so small as to be entirely non-significant.

## PALATABILITY FACTOR

One result which is not shown in the data but which was very obvious to those concerned in the trial was that the malt sprout-barley screening combination was unpalatable to the extent that it was difficult to get the cows to clean up their entire allowance.

While this combination would quite readily soak up four times its weight in water, the resulting mash was of a heavy, soggy nature. It did not increase its volume anything like as much as did the beet pulp when soaked.

When the cattle first started on the feed they ate this malt sprout-barley screening material quite readily, but seemed to tire of it after a week or ten days of feeding. It was the opinion of the feeders that the lack of palatability of this product was a limiting factor in its usefulness.

As a matter of comparison, a few cows outside of the two test groups were fed a succulent mixture consisting of 50 per cent by dry weight of beet pulp and 50 per cent of the malt sprout-barley screening combination. No data were recorded as to quantities of feed used, the object being merely to observe the palatability of this combination.

The difference in this respect was quite noticeable. Cattle on this mixture appeared to relish it and cleaned it up quite as readily as they did the straight beet pulp. The material soaked much more satisfactorily and the resulting product was more bulky and in every way more suitable for a succulent feed for dairy cattle.

## Conclusions

1. While from a nutritional standpoint no measurable difference as a succulent feed for dairy cattle was observed after thirty days of feeding soaked beet pulp as compared to a soaked malt sprouts-barley screening-molasses combination, the palatability of the latter combination was a limiting factor in its use.

2. A combination of equal parts of beet pulp and malt sprouts-barley screenings as a succulent feed for dairy cows proved entirely palatable and apparently satisfactory when soaked in four times its weight of water.

## CURRENT PUBLICATIONS

17. An Etymological Dictionary of Chemistry and Mineralogy. Dorothy Bailey and Kenneth C. Bailey. Edward Arnold & Co., London. 1929.

18. A Chemical Dictionary, containing the words generally used in Chemistry and many of the terms used in the related sciences of Physics, Astro-physics, Mineralogy, Pharmacy and Biology with their pronunciations, with elaborate tables, diagrams, portraits and many other illustrations. Hackh, Ingo W.D., P. Blakiston's Son & Co. Inc., Philadelphia. 1929.

Students of agriculture often feel the need of dictionaries giving the pronunciation, etymology and definition of terms used in the various sciences underlying their subject. These two books represent pioneer attempts to fill this need with special reference to chemistry. The scope of the books is suggested by the titles. The first-mentioned gives etymologies, the second pronunciations. The first confines itself mainly to the names of substances and of minerals; the second includes also names and pictures of pieces of apparatus and of eminent chemists and, as the long title implies, a number of tables, diagrams and structural formulae. Being of wider scope and considerably greater size, the American book has probably a larger proportion of errors than the English one. The agricultural student is warned against the erroneous definitions of Paris Green, Bordeaux mixture, Reichert-Meissl number and Polenske number. An amusing error in the English book is the reference under "Cookeite" to Professor J. P. Cooke, a former head of the Chemistry Department of Harvard University, Cambridge, Mass., as "Professor J. P. Cooke of Cambridge."

There appear to be more terms peculiar to each work than common to the two, the Bailey work being fuller as regards mineral names and the Hackh book having many terms beyond the scope of the other. Both are admirable pieces of work and will undoubtedly prove very useful. J.F.S.

# THE PHYSIOLOGY OF RHIZOCTONIA [1]

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[Received for publication February 5, 1931]

## 1. The Thermal Death Point of Vegetative Cultures

Large losses occur in British Columbia through the Black Scurf Disease of potatoes, caused by *Rhizoctonia solani* Kühn. Owing to the variable field symptoms it seemed desirable to ascertain whether physiological strains existed. Fifteen isolations of the fungus were made (hereafter referred to as "strains") from infected tubers grown at widely divergent points in British Columbia, but no significant differences were observed in the morphological characters or pathogenicity of the same. It appeared possible that the thermal death point of vegetative cultures might reveal physiological differences between the strains.

Potato dextrose and synthetic agar plates were inoculated with each strain and incubated at 25°C until the colonies half filled the plates. They were then maintained for sixty minutes at temperatures ranging from 35° to 60°C and they were again transferred to a 25°C incubator. The growth rates of normal and heated cultures were compared. In the case of all strains of *Rhizoctonia solani* the temperature had no significant effect up to 45°C. At 50°C all cultures were killed. For comparative purposes two strains of *Rhizoctonia crocorum* Pers. were included in these experiments. The strains were isolated from alfalfa grown near Vancouver and Trail, B.C., respectively. Unlike the cultures of *R. solani*, those of *R. crocorum* were injured at 45°C, as indicated by a lag in the growth when again transferred to a 25°C incubator, and by the occasional death of cultures so treated.

Agar plate cultures were maintained for fifteen, thirty, forty-five and sixty minutes at 50°C. Fifteen minutes caused a lag in the growth of *R. crocorum*, but had little effect upon *R. solani*. However, longer periods caused a distinct lag in the growth of *R. solani* and cultures maintained at 50°C for forty-five minutes occasionally died. After sixty minutes all cultures of both species failed to revive. Typical results are shown in figure 1.

It was of interest to find that no permanent attenuation occurs in vegetative cultures of Rhizoctonia as the consequence of maintaining them at temperature periods near the lethal point. Although the growth rates are inhibited temporarily by the heat treatments, such cultures again acquire a vigour equal to that of their original state. Therefore, the effectiveness of hot formaldehyde or hot mercuric chloride treatments are entirely dependent upon the greater penetration or the greater toxicity of these disinfectants at the higher temperatures rather than upon any direct effect of the heat upon the fungi. In view of the fact that potato tubers fail to make any significant growth after being immersed for one hour at 50°C

1 Contribution from the Division of Botany, Experimental Farms Branch.
2 Plant Pathologist-in-charge.

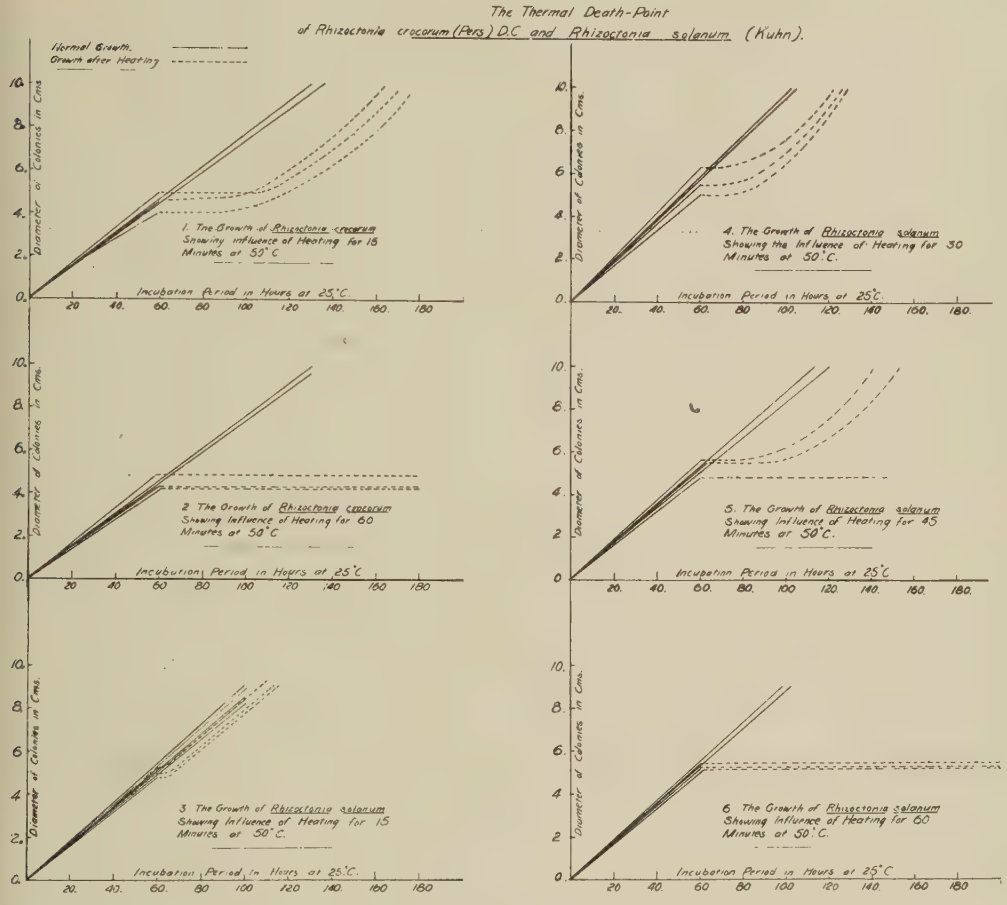
The Thermal Death-Point
of Rhizoctonia crocorum (Pers.) D.C and Rhizoctonia solanum (Kuhn).
Normal Growth.
Growth after Heating
Diameter of Colonies in Cms.
Incubation Period in Hours at 25°C.
1. The Growth of Rhizoctonia crocorum Showing influence of Heating for 15 Minutes at 50°C
2. The Growth of Rhizoctonia crocorum Showing Influence of Heating for 60 Minutes at 50°C
3. The Growth of Rhizoctonia solanum Showing Influence of Heating for 15 Minutes at 50°C.
4. The Growth of Rhizoctonia solanum Showing the Influence of Heating for 30 Minutes at 50°C.
5. The Growth of Rhizoctonia solanum Showing Influence of Heating for 45 Minutes at 50°C.
6. The Growth of Rhizoctonia solanum Showing Influence of Heating for 60 Minutes at 50°C.

Figure 1.

and are severely injured when immersed for the same period at 45°C, the hot water treatment has no significance in the control of *Rhizoctonia solani*. Furthermore, sclerotia of this fungus germinated after being removed from tubers immersed for one hour at 55°C. The lethal temperature period was one hour at 60°C.

## Summary of Part I.

The lethal temperature period for vegetative cultures of *Rhizoctonia solani* was one hour at 50°C. Shorter periods at the same temperature caused a lag in the growth rate when the cultures were transferred to an incubator at 25°C. The lethal temperatures of vegetative cultures of *R. crocorum* were slightly lower than those of *R. solani*.

Potato tubers immersed for one hour at 45°C were severely injured, at 50°C were killed and at 55°C sclerotia germinated that were removed from the immersed tubers.

## II. The Growth Rate as Influenced by Temperature

The available information on the growth rate of filamentous fungi as influenced by temperature has been obtained largely by measuring the diameter of petri dish cultures. This method was subjected to a critical examination by Fawcett (*1*). He found that the optimum temperature shifted to lower temperatures for each successive twenty-four hour observation period during incubation periods of from three to six days in length. Therefore, as determined by measuring the diameter of petri dish cultures, the temperature optimum of any filamentous fungi is not a critical constant. It varies with the period of observation even when all other experimental conditions are standardized. Also, Fawcett's data show that there is a progressive increase of the temperature coefficient of filamentous fungi as the temperature is lowered. At a low temperature the temperature coefficient is so large, that the fluctuations of $\pm$ 1.0°C of an ordinary laboratory incubator are likely to create a large experimental error. Standard constant temperature water baths fluctuate to a lesser degree, not more than 0.1°C, and hence a smaller error is involved if they can be used in growth rate studies.

In studying the growth rate of *Rhizoctonia solani* Kühn as influenced by temperature, an attempt was made to develop an experimental procedure that would establish the optimum temperature and the growth rate at any temperature as critical constants. The studies of Fawcett (*2*) on the maintained growth rates were suggestive that maintained constant growth rates at constant temperatures could be obtained if filamentous fungi were grown in tubes.

### Experimental

The fungus was grown on a standard nutrient medium poured into sterile glass tubing held in a horizontal position so that when the agar solidified, a little less than half the diameter of the tubes was filled with the solid nutrient medium. Glass tubing with an inside diameter of 6 mm. was found to be the most satisfactory size. A standard length of 50 cm. was adopted of which 2.5 cm. was bent upward at either end. These were plugged with cotton wool, sterilized, and 6 cc. sterile agar poured in while the tubes were hot. With a little practice a uniform layer of solid agar can be obtained throughout the length of the tube with the exception of the bent portions at the ends.

It is essential that the agar layer be uniform in thickness for the growth rate is affected by the thickness of the agar layer. This was proved by drawing hot sterile agar through cold sterile 4 mm. (inside diameter) glass tubing. The agar adhered to the tubing but not in a uniform layer. Although the fungus grew rapidly along such tubes, the growth rates were not constant under comparable conditions.

When the agar solidified, the tubes were inoculated at one end with sections cut with a sterile cork borer from the external boundary of petri dish colonies approximately 4 cm. in diameter grown at 25°C. The tubes then were placed in an incubator at 25°C until the fungus had grown along the tubes about 2 cm. Afterwards, the inoculated ends were sealed

over the cotton plugs with DeKhotinsky cement and the tubes were immersed in a constant temperature water bath, with the exception of the unsealed ends. The frontier of the advancing mycelia was traced on the tube with waterproof ink, and at subsequent intervals the new boundaries were traced, and the increments of growth were measured. At short intervals the increment of growth was measured by means of the microscope.

In general the growth rate increased until the mycelia had advanced 2 to 4 cm. along the tube, but finally a growth rate was obtained that remained constant within a 2 per cent error until the mycelia completely filled the tubes.

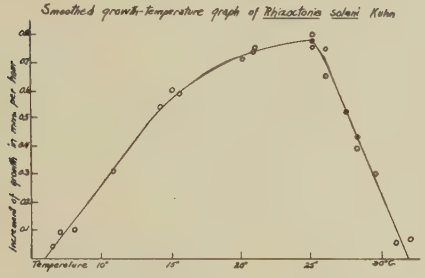


Figure 2.

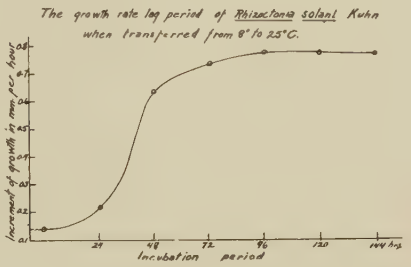


Figure 3.

The constant growth rates were determined for a series of temperatures and figure 2 is the growth temperature graph obtained. The shape of this graph indicates that the temperature coefficient is very large at low temperatures and progressively decreases as the temperature is raised. Although others (*1, 3, 4, 5*) have found this phenomenon to be characteristic of many biological processes, it was found in these studies that the advancing mycelia progressively became more sparse and spindly as the temperature was lowered; therefore, the temperature coefficients at low temperatures calculated from figure 1 are larger than would be obtained if the growth rates were determined by weighing the mycelia.

When the tubes were transferred from a low temperature to one closer to the optimum, a lag period occurred. This lag period appeared to be a function of the difference in temperature for it was longer when the tubes were transferred from 8° to 25°C than in the case of any intermediate temperature transfer. The data used in the construction of figure 3 were obtained from triplicate tubes transferred from an 8°C bath where they had been growing for 21 days to a bath at 25°C. Under these conditions a constant growth rate at 25°C is not obtained until the fourth day.

## Summary of Part II.

(1) A method is described for obtaining critical growth temperature constants.

(2) The growth temperature graph for *Rhizoctonia solani* Kühn reaches zero at 6°C and 32°C and an optimum growth rate at 25°C. The shape of the graph indicates that the temperature coefficient progressively increases as the temperature decreases.

(3) When tube cultures were transferred from 8°C to 25°C a constant growth rate was not obtained until the fourth day.

## REFERENCES

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3. Leich, I. Some experiments on the influence of temperature on the rate of growth in *Pisum sativum*. Ann. Bot. *30*; 25-46. 1916.
4. Livingston, B. E. Physiological temperature indices for the study of plant growth in relation to climatic conditions. Physiol. Res. *1*; 399-420. 1916.
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## CURRENT PUBLICATIONS

19. Agricultural Machinery. J. Brownlee Davidson. John Wiley & Sons, New York.

Until a few years ago text books on farm machinery were few in number and those which were available covered rather an incomplete list of this equipment. The outstanding qualifications of Professor Davidson's new book are the facts that it includes descriptive material of a greater range of farm machinery than does any previous work and is strictly up-to-date in its information.

In addition to the usual chapters on various tillage and harvesting equipment this book contains very useful material in elementary mechanics, the design of agricultural machinery, and materials used in its construction. Very useful information is also included on grain cleaning equipment, farm pumps, spraying and dusting machinery, milking machines and grinders, including hammer mills.

This book should be of great use to agricultural engineers and others who are developing courses of instruction in this subject. L.G.H.

20. The Plight of Cigarette Tobacco. T. J. Woofter, Jr. Chapel Hill, University of North Carolina Press, 1931. Available on loan from the Tobacco Division Library, Central Experimental Farm, Ottawa.

"This is a study of conditions which are extremely unfavourable to the farmer in marketing America's sixth most important crop, and of the economic forces which have created these conditions. It is an analysis of the factors which determine the price paid to farmers for leaf tobacco, with special reference to the significance of these factors to a co-operative marketing programme." (Author's preface). The topics dealt with include a discussion of tobacco as a commodity, costs of production, the manufacturing industry, the auction market system, taxation, relations of consumption and production to farm price and the merits of co-operative marketing. T.G.M.

# "LA TECHNIQUE AGRICOLE INTERNATIONALE"

## Revue Trimestrielle de la Federation Internationale des Techniciens Agronomes (F.I.T.A.)

Franco Angelini
*Dr. ès. sc. agr., Député Général de la F.I.T.A.*

Cette Revue doit remplir le double emploi d'apporter un message et de servir d'instrument pour la divulgation des progrès de la technique agricole. Elle sera le messager de l'esprit de fraternité dans la vie rurale qui doit réunir les techniciens agronomes de tous les pays dans un sentiment de solidarité et d'intérêt commun, au bénéfice de toute la Nation. En même temps elle propagera, au moyen d'articles originaux et de résumés des travaux d'autrui, tous les résultats acquis dérivant des études, des expériences et des applications pratique accomplies par les techniciens agronomes, dans le but d'assurer aux populations une plus grande quantité de produits alimentaires, ainsi que de renforcer la puissance de leur économie rurale.

Depuis longtemps déjà se faisait sentir la nécessité d'une publication internationale qui puisse mettre bien en relief et protéger les intérêts matériels et moraux des techniciens agronomes, qui puisse faire connaître les résultats des diverses orientations techniques et économiques qui se manifestent dans les divers pays et qui puisse porter à la connaissance des agronomes de profession les progrès pratiques obtenus et mis en valeur au moyen de diverses modifications et adaptations des nouvelles méthodes et des procédés nouveaux.

Ce ne seront donc point les résultats des recherches scientifiques particulières, ni ceux des études et des analyses spéciales qui fourniront la matière traitée par cette Revue, mais bien les procédés et les instruments propulsifs et organisateurs de notre activité professionnelle, dans le but de mettre en valeur et d'appliquer l'oeuvre des techniciens, aussi bien pour ce qui concerne directement leur compétence et leur activité, qu'en vue de la nécessité d'organiser la technique de la production. La Revue traitera encore divers sujets qui pourront servir et renseigner les techniciens agronomes sur tout ce qui porte l'empreinte de leur activité et de leur contribution au bien-être matériel et économique des divers pays.

Il faut prendre en considération que la catégorie des agronomes de profession exerçait jusqu'ici son activité dans diverses branches plus ou moins reliées entre elles, sans avoir ni une situation, ni une physionomie précise et bien déterminée, tandis qu'aujourd'hui elle assume une responsabilité de direction plus délicate; elle a obtenu cette importance, grâce aux mérites particuliers qu'elle a su acquérir, en contribuant au rétablissement de la paix économique entre les Etats, ainsi qu'en vertu des études sérieuses qu'elle a noblement entreprises et des oeuvres qu'elle a accomplies dans l'intérêt commun. Les nouvelles fonctions de direction auxquelles sont appelés les techniciens agronomes proviennent donc surtout de la plus grande estime qu'ils ont gagnée, en démontrant l'utilité pratique de leurs travaux.

Il s'ensuit la nécessité d'une organisation à structure plus large, plus compacte et plus solide, qui a trouvé son expression évidente dans la constitution de notre Fédération Internationale.

Les avantages que présente cette Revue sont donc de réunir en une seule expression les opinions et les renseignements divers et de constituer un nouveau lien solide entre les techniciens agronomes du monde entier.

Il est facile à prévoir qu'il en résultera une plus grande efficacité de leur oeuvre, une augmentation de la fréquence de leurs relations réciproques et de l'influence qu'ils exercent sur l'économie des pays qui sont particulièrement intéressés aux progrès de leur industrie agricole.

Enfin, cette action commune et cette collaboration devront présenter un avantage moral très appréciable pour les techniciens qui désirent élargir le champ de leur activité en conformité avec leur compétence spécifique, dans l'intérêt d'une production plus ample et plus avantageuse, qui rehausse justement la valeur économique et sociale de leur oeuvre. C'est avec ces intentions et dans ce dessein que nous entreprenons la publication de la présente Revue, en adressant un salut de chaleureuse cordialité aux collègues de tous les pays qui partagent et apprécient ces vues.

21. The Economy of Machine Production in Agriculture. Andrew Stewart, Essays on Canadian Economic Problems, Vol. IV, The Royal Bank of Canada Economic Fellowship Competition 1930-31.

With a view to encouraging a systematic study of the economic problems of the country, The Royal Bank of Canada offers an annual One Thousand Dollar Graduate Fellowship to the student in attendance at any Canadian university who shall submit the best paper on one of a number of specified subjects The winning 1930-31 paper by Mr. Andrew Stewart of the Manitoba Agricultural College was prepared under the direction of Dr. Murchie. An announcement of the competition for 1931-32 may be found in the Notes and News section of this month's issue of *Scientific Agriculture*.

Mr. Stewart's thesis covers the following ground:

Part I. Historical review of agricultural machinery.
" II. Some general results of the mechanization of agriculture.
" III. Developments in Canadian agriculture during the last fifty years.
" IV. Tractors.
" V. Combines.
" VI. Present day trends.
" VII. Conclusion.

In 'Present day trends' we get a careful analysis of the effect of mechanization on both specialized and diversified farming in Western Canada. The thesis as a whole is clear, concise and well reasoned and is a credit to the author and to the sponsors of the competition. In his conclusion Mr. Stewart states that, 'There is no reason to believe that farm machinery has reached its maximum efficiency, or that the experience of history will not be repeated in the future and a growing mechanization of agriculture be evident. The economy of machine production makes it inevitable'.

22. Recent Advances in Pasture Management. O. McConkey, Empire Marketing Board 43, printed and published by H. M. Stationery Office, London. Price 1s. 0d. net.

This bulletin was prepared by Dr. McConkey of the Ontario Agricultural College while he was spending two years in Europe studying recent developments in grassland research. While grassland products form only 17 per cent of the total exports of Canada as compared to 94 per cent for New Zealand and 60 per cent for Australia, there is room for great improvement in pastures supplying products to our domestic as well as foreign markets. An idea of the importance of pastures to the Empire is gained when we note that the consumption of grassland products in the United Kingdom is valued at nearly four times the consumption of wheat.

The bulletin includes a discussion of pasture research in the Empire and Europe, the need for controlled methods of seed production and distribution, and the nutritive value of pastures. The principal of rotational grazing with heavy manuring is upheld, and the use of minerals and the variations in grazing due to species are discussed. Acknowledgment is made particularly to the Director and staff of the Welsh Plant Breeding Station at Aberystwyth, Wales, whose Director, Professor R. G. Stapledon, is also Director of the Imperial Bureau of Plant Genetics (Herbage). The bulletin contains also a list of the publications of the Empire Marketing Board, copies of which may be secured on loan from the Dominion Department of Agriculture Library, Ottawa.

23. Proceedings, Lime Conference. Held at the University of Tennessee Agricultural Experiment Station, Knoxville, October 6, 7, 8, 1930.

This publication presents the verbatim report of a conference of forty-five fertilizer specialists representing the research and commercial interests of fifteen states. Most of the discussions were of interest mainly to the soil chemist. The Report of the Committee on Recommendations for the Practice of Liming is signed by L. G. Willis of the North Carolina State College, Raleigh, N.C., S. D. Conner of Purdue University Agricultural Experimental Station, Lafayette, Ind., and F. C. Bauer, University of Illinois Agricultural Experiment Station, Urbana, Ill. This report, covering twenty-six items discussed, includes the following recommendations of interest to extension workers:

"6. The use of small amounts of lime in the drill for crops such as red clover and alfalfa is not a dependable practice on very acid soils. On soils where heavy liming produces

unfavourable response, or where the acidity is slight, this method of application has much promise. Where disease is a limiting factor in the use of lime, applications in the drill may offer no advantages. This method of using lime should be studied further."

"17. The use of ground limestone, pre-mixed with fertilizer, has much to commend it in theory, and many observations point to its value in practice. It appears possible to mix ground dolomitic limestone with well-cured superphosphate without risk of extensive reversion."

"22. It appears advisable to apply lime well in advance of seeding the clovers and alfalfa to avoid the possibility of poor stand that often follows planting shortly after liming."

The complete Proceedings may be borrowed from the Department of Agriculture Library, Ottawa.

24. Condensed Report on Vitamin Investigations, Study of Vitamins A and D in Butterfat. A. L. Gibson. MS in Department of Agriculture Library, Ottawa. Complete copies of thesis in University of Toronto and Ontario Agricultural College Libraries.

This thesis covers the author's work in England on the ultra-violet irradiation of butter fat, Vitamin A tests of butter fat from cows on special diets, the effect of hydrogenation (hardening) of cod liver oil on Vitamin D content, and tests on patented anti-rachitic foods.

Of special interest to Canadian workers is the establishment of and directions for the management of a rat colony at the Ontario Agricultural College, and the testing of the vitamin properties of butter fat from various breeds of cattle. It was found that butter fat produced by cows of the Ontario Agricultural College herd was potent in both Vitamins A and D when produced on either good normal winter diet or summer diet. The actual amounts of Vitamins A and D per unit of butter fat produced from the Jersey, Ayrshire and Holstein breeds kept at the Ontario Agricultural College do not vary when all breeds receive the same diet. It was also found that milk, cheddar cheese and ice cream from the Ontario Agricultural College Dairy Department possessed a good supply of Vitamin A, milk and cheddar cheese being completely anti-rachitic.

25. Contributions from the Giannini Foundation of Agricultural Economics. Papers 1-10, University of California, College of Agriculture.

Through the generosity of Amadeo Pietro Giannini there has been established the Giannini Foundation of Agricultural Research at the University of California. The Foundation is an integral part of the College of Agriculture and is housed in Giannini Hall which was formally dedicated on October 21, 1930.

This volume gathers the first ten papers published by the Foundation. These include Californian economic papers on sheep, walnuts, enterprise efficiency studies, asparagus, and cherries. There are three general papers on 'The Scope and Methods of Research in Land Utilization', by David Weeks; 'Use, Value and Cost of Credit in Agriculture', by Charles West; 'The Farm Board' and 'The Potato Industry' by E. A. Stokdyk. The most comprehensive study is a 350 page report by B. H. Crocheron and W. J. Norton on 'Fruit Markets in Eastern Asia'. The address at the dedication of Giannini Hall by Dean Albert R. Mann of Cornell University on "Agricultural Economics and Agricultural Evolution" sums up many of the opinions expressed at the International Conference of Agricultural Economists held at Cornell in 1930.

26. Household Insects and Their Control. Arthur Gibson and C. R. Twinn. Dominion Department of Agriculture Bulletin No. 112 New (Revised). Available from the Director of Publicity, Department of Agriculture, Ottawa.

This bulletin should be in every well managed home. It is a complete manual on the identification and control of household pests as it includes a chapter on 'Animal Pests other than Insects found in and about Dwellings'. There is also a chapter on the identification of fruit and vegetable insects, pointing out what portions of damaged food material may be used and urging the destroying of insects rather than permitting them to live in garbage.

In addition to their reliability, a feature of the bulletins published by the Entomological Branch is their attractive covers and the general excellence of their illustrations. The authors present many photographs, and credit is also due to Mr. Frank C. Hennessey, artist of the Entomological Branch, for his many excellent drawings and cover designs.

## Notes and News

H. W. E. Larson (Oregon '28) has changed his address to 430 North Lake Street, Madison, Wis.

J. H. Maduke (Saskatchewan '28) has changed his address to 506—11th Street East, Prince Albert, Sask.

L. R. Finlayson (McGill '29) has changed his address to Dominion Parasite Laboratory, Belleville, Ont.

H. N. Bergsteinsson (Manitoba '30) is now at the University of Saskatchewan, Saskatoon.

R. P. Longley (Toronto '31) is at the University of Toronto for the winter. His address is 417 Strathmore Boulevard, Toronto.

J. H. Tessier (Montreal '25) has changed his address to Pierreville, Yamaska County, P.Q.

J. C. Woodward (McGill '30) has resigned his position as Assistant Agriculturist at Lennoxville, P.Q., and is doing graduate work for his M.Sc. degree at Cornell University. His address is 319 College Avenue, Ithaca, N.Y.

H. S. Cunningham (McGill '17) has been appointed Plant Pathologist at the Long Island Vegetable Research Farm of the New York State Experiment Station at Riverhead, N.Y.

F. J. Welland (British Columbia '23) has accepted the position of Principal of MacLean High School at Port Haney, B.C. His address is P.O. Box 161, Port Haney.

C. M. Collins (McGill '22) is doing graduate work in Economics at the University of Toronto. His address is 48 Huntley Street, Toronto.

G. A. Ledingham (Saskatchewan '27) is at the University of Toronto, Botany Department, for the winter.

L. T. Wilson (Saskatchewan '24) has accepted a position with the Walker-Gordon Laboratories at Plainsboro, New Jersey, U.S.A.

J. B. Rutherford (Saskatchewan '30) is doing graduate work in Agricultural Economics at Iowa State College, Ames, Iowa.

T. Stevenson (Saskatchewan '23) is doing graduate work in Plant Genetics at the University of Minnesota, St. Paul, Minn.

B. J. Sallans (Manitoba '21) is doing graduate work in Plant Pathology at the University of Wisconsin. His address is 305 Lathrop Street, Madison, Wis.

Michael Peech (Saskatchewan '30) is doing Soil Research work at the University of Ohio. His address is 26 West 10th Avenue, Columbus, O.

L. E. Kirk (Saskatchewan '16), recently appointed Dominion Agrostologist, has arrived in Ottawa and taken up his work at the Central Experimental Farm.

R. W. Murchie (Glasgow '06), head of the Department of Economics and Sociology at Manitoba Agricultural College, has accepted the position of Professor of Rural Sociology and Director of Rural Social Research at the University of Minnesota. Dr. Murchie has been on the staff of the Manitoba Agricultural College since 1915 and for the past two years has been Director of the Farm Economic Service of the Pioneer Problem Committee of Canada, which position he will not relinquish until the studies are completed.

The following student members have advised their changes of address:

J. F. Allan—1119 Temperance Street, Saskatoon.

H. L. Patterson—Cornell University, Ithaca, N.Y.

## THE ROYAL WINTER FAIR

November 18-26, 1931.

Those whose view of the future is too near the present for a true perspective will find cheer and encouragement in reviewing the amazing advances made since the war in all branches of Canadian activity. If past experience is a sound guide, Canada is now having a breathing spell to gather fresh energy for a still greater forward movement.

This steady national advancement is symbolized most impressively in the Royal Agricultural Winter Fair, which this year is commemorating its tenth anniversary. Compared

with the first show held in 1922, the Royal of 1931 is in an immensely improved position in the matter of equipment for the housing and exhibit of the thousands of entries in all departments, gathered annually from every part of Canada and from the United States. The Fair reaches its tenth birthday with an established international reputation; its position of leadership in buildings and equipment is backed by even more important assets, the loyal enthusiasm of exhibitors and the steady and encouraging support accorded by the public. In a sense, the last decade has been for the Royal a period of pioneering. The enthusiasm of exhibitors has always run so far ahead of accommodation as to justify the important extensions to the original buildings; the Live Stock Buildings were completed in 1927, and the magnificent new Equerry Building, to house 1,200 horses in comfort, will be inaugurated this year.

The Royal this year is designed to commemorate its founding and inauguration ten years ago, when in the depression that followed the war it helped so signally to restore confidence to Dominion agriculture generally. Since its 'birthday' at that time it has established itself as an institution to which Canadians all over Canada have pointed with a very considerable pride.

The Royal is entering upon its new cycle under conditions which permit it to perform a service to Canada in influencing the general outlook and state of mind of the Canadian people, apart altogether from its influence upon agriculture. The aim of the management is that everyone who visits the Royal and everyone who exhibits there shall be better equipped to meet whatever problems may cross their path in the immediate future.

A welcome and refreshing tone of confidence in Canadian agricultural conditions is sounded in the announcement by the management of the Royal Winter Fair that "prospects for entries at the Royal in all departments were never better than at the present moment".

"Exhibitors in the western Provinces are most anxious to continue to display their live stock and other agricultural products", the Royal's statement goes on, "and the Dominion Government and the Provincial Governments, recognizing the advantages of the Provinces continuing to occupy a prominent position at the Royal are contributing their usual financial assistance in transportation and in the selection of the live stock and agricultural products.

"There has been more than the usual number of inquiries from United States points this year and the Royal's survey of Ontario and Quebec indicates that there is considerably more live stock than usual ready for exhibition, so that we are very satisfied that the Winter Fair will open with the best and most representative live stock displays which we have ever had."

Although general conditions last November were anything but favourable, 1930 was the Royal's record year, not only in exhibits and attendance, but the spirit of the people at the show was happier than at any previous event. We feel sure that the spirit of optimism at that time has served a very useful purpose in that it has enabled Canadians better to view recent economic adjustments with equanimity.

### The Royal Bank of Canada Economic Fellowship Competition

The Royal Bank of Canada will grant a One Thousand Dollar Fellowship or a Cash Prize of Two Hundred and Fifty Dollars to the graduate or under-graduate student of a Canadian university who writes the best paper not exceeding three thousand words in length, on any one of the following subjects during the academic year of 1931-32. The student winning the prize may select either the $1,000 Fellowship at any university in Canada, or $250 in cash.

The Wheat Situation at Home and Abroad.

Price Stabilization.

(It is the intention in connection with this subject to permit wide latitude of discussion).

The Degree of Diversification, Present and Potential, in Farming in Western Canada.

Social Legislation.

(Old Age Pensions and Unemployment Insurance in Canada).

The papers must be submitted in triplicate through the Economics Department of the university which the student is attending, to the Economist's Department of The Royal Bank of Canada, before March 1, 1932. They should be typewritten and numbered. The name of the student should be submitted in a sealed envelope, together with a statement from the university that the student is in full time attendance during the academic year 1931-32.

Candidates are given the option of submitting a thesis of any length desired, together with the three thousand word essay, which shall be an abstract of the thesis. The submission of the thesis is not obligatory; only one copy of this thesis is required. The papers become the property of the bank and may be published as the bank sees fit. Since the judges' decision is based primarily on the essay, it is advisable that this paper shall be complete in itself and that it shall be just as carefully written as though it were the only document submitted. It is a notable fact, however, that the judges in the 1930-31 competition gave first and second place to essays accompanied by longer papers.

### Dominion Department of Agriculture Housed in New Quarters

During the last few months various branches of the Dominion Department of Agriculture have been moving to permanent quarters in the newly constructed Confederation Building at the corner of Bank and Wellington Streets, Ottawa. The many branches which have been scattered over the city are now under one roof, with the exception of the Dairy Research Laboratories and the Seed Laboratories; the Dominion Experimental Farm and the Animal Research Institute in Hull retain their permanent quarters. In the new building the various branches may be found as follows:

| | |
|---|---|
| Publications | Basement. |
| General Administration Offices and Dairy Branch | Fourth Floor |
| Livestock and Economics | Fifth Floor |
| Entomological and Seed | Sixth Floor |
| Health of Animals and Fruit | Seventh Floor |
| Main Library | Ninth Floor |

The remaining floors of the building are occupied by the Department of Labour on the first floor, the Auditor-General on the second and third and the Penitentiaries Branch on the eighth floor.

It is especially pleasant to visit the commodious quarters of the library on the top floor. Miss A. M. Shaw, who is to be congratulated on having built up a very fine agricultural library, is arranging to have it open at all hours of the day. Members of the Department of Agriculture will find this especially convenient at noon.

### C.S.T.A. Directors' Meeting at Royal Winter Fair

The annual C.S.T.A. Directors' meeting will be held on Friday, November 20th, at 2 p.m., in the Royal York Hotel, Toronto. Included in the many important items of business will be voting on non-graduate members, re-arrangement of the duties of Committees, financial affairs, 1932 Convention and publications policies. It is expected that the General Secretary will be able to attend the meeting.

### C. S. T. A.—O. A. C. Alumni Banquet

The annual joint banquet held at the time of the Royal Winter Fair will take place in the Venetian Café of the Royal York Hotel at 6.30 p.m. on Friday, November 20th. This event has always been enjoyed greatly by O.A.C. and C.S.T.A. men. At the time of writing the name of the principal speaker cannot be definitely announced, but a good programme is assured. Tickets may be secured from officials and members of the Toronto local of the C.S.T.A. and of the Ontario O.A.C. Alumni Association, as well as from the General Secretary, who will be located at the Royal York Hotel. Last year the banquet hall was crowded and it would be advisable to secure tickets for this banquet as early as possible.

## SELECTED LIST OF ACCESSIONS TO THE LIBRARY OF THE DOMINION DEPARTMENT OF AGRICULTURE.

*(Members of the C.S.T.A. may borrow these postfree by addressing a request to the Library, Department of Agriculture, Ottawa).*

Allee, W. C. Animal aggregations; a study in general sociology. Chicago, University of Chicago press, 1931. 431 p. Bibl. pp. 365-409.

Alliaume, André. Les skunks; animaux à fourrure; notions de zoologie, de pathologie et d'élévage. Paris, Vigot frères, 1930. 64 p. Bibl. pp. 61-2.

Annuaire Lambert. Fasc. 11, 1928-30. Statistique des engrais et produits chimiques destinés à l'agriculture. Paris, Bureau d'études économiques, industrielles et agricoles, 1931. 80 p.

Bartlett, R. W. Co-operation in marketing dairy products. Springfield, Ill. Charles C. Thomas, 1931. 299 p. il. $4.00.

Bergeon, P. La peste bovine au Tonkin et la vaccination antipestique. Hanoi, Imp. G. Taupin et cie. 1930. 35 p. Bibl. pp. 34-5.

Canada. Dept. of trade & commerce. Foreign markets for Canadian certified seed potatoes. Ottawa, 1930. 42 p. il.

Clausen, C. P. Insects injurious to agriculture in Japan. Washington, D.C. 1931. 115 p. map. (U.S. Dept. of agriculture. Circular 168). Bibl. pp. 92-103.

Conference on development of agricultural co-operative business. Report. Aberystwyth, Wales, 1931. 35 p. tpw.

Dalgety's annual wool review for Australia and New Zealand. Vol. 33. 1930-31. Sydney, NSW. 1931. 181 p.

Florinsky, M. T. The end of the Russian Empire. New Haven, Yale university press, 1931. 272 p.

Giannini foundation of agricultural economics. Contributions. Papers 1-10. Berkeley, Calif. 1930. 366 p.

Gibson, A. L. Condensed report on vitamin investigations; study of vitamins A and D in butterfat. Guelph, Ont. 1931. 52 p. photos.

Graton & Knight. Leathercraft. 3d ed. Worcester, Mass., Graton & Knight co. 1929. 124 p. il.

Gt. Brit. Ministry of agriculture and fisheries. Agricultural machinery testing committee. First report. London, 1931. v.p.

Gt. Brit. Ministry of health. A memorandum on bovine tuberculosis in man with special reference to infection by milk. London, 1931. 25 p.

Grieve, Mrs. M. A modern herbal; the medicinal, culinary, cosmetic and economic properties, cultivation and folklore of herbs, grasses, fungi, shrubs, and trees, with all their modern scientific uses. London, Jonathan Cape, 1931. 2 vols.

Herrington, Arthur. The chrysanthemum; its culture for professional growers and amateurs. New York, Orange Judd pub. co. inc. 1929. 158 p. il.

Howard, L. O. The insect menace. New York, The Century co. 1931. 347 p. illus.

Hubert, E. E. An outline of forest pathology. New York, Wiley & sons, inc. 1931. 543 p. il.

Huyen, P. V. La vaccination antirabique chez les animaux; recherches sur un vaccin glycéro-formolé. Paris, Pierre Bossuet, 1930. 126 p. Bibliographie pp. 113-22.

Imperial bureau of plant genetics: Herbage plants. Research in progress on herbage plants, forage crops and general grassland problems in the British Empire. Aberystwyth, Wales, 1931. 52 p. (Bulletin no. 5).

Johnson, C. W. A list of the insect fauna of Nantucket, Mass., with a list of spiders, by J. E. Emerton. Nantucket, Mass. 1930. 175 p. (Nantucket Maria Mitchell association. Publications. vol. 3 no. 2).

Jones, Arthur and Makings, S.M. Some aspects of meat distribution and consumption. Sutton Bonington, 1931. 93 p. (Midland agricultural college. Dept. of agricultural economics. Survey studies no. 2).

Jull, M. A. Progressive poultry raising. Chicago, Armour's livestock bureau, 1931. 222 p. illus.

Kluyver, A. J. The chemical activities of micro-organisms. London, University of London press, ltd. 1931. 109 p. References pp. 105-09.

Kratz, A. P. Humidification for residences. Urbana, Ill. 1931. 30 p. (Illinois. Engineering experiment station. Bulletin 230).

The leather trades' year book. Vol. 29, 1931. London, 1931. 323 p.